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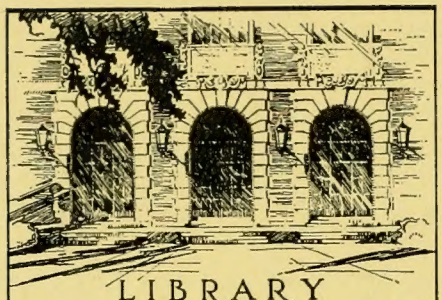
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LAKE MANAGEMENT REPORTS

4. A Second Year of Fisheries Investigations at Fork Lake, 1939

George W. Bennett

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4. A SECOND YEAR OF FISHERIES INVESTIGATIONS AT FORK LAKE, 1939

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Illinois Natural History Survey,
and
Sam A. Parr,
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This report covers the fisheries investigations done at Fork Lake, near Mount Zion, Illinois, in 1939. Although our conclusions are intended to apply to Fork Lake itself, a body of water of 1.38 acres, they may be extended to include other similar, small artificial lakes. In an earlier report (Thompson & Bennett 1939a) investigations in Fork Lake during 1938 and recommendations for future management were discussed. It may be well to repeat here the principal points. Poison was applied to the lake and a fish census was made which showed 744 pounds of fish, of which 37 pounds were hook-and-line fish of legal length. The lake was then restocked with 1,440 largemouth bass fry, *Huro salmoides* (Lacépède), and with 270 breeder bluegills, *Lepomis macrochirus* (Rafinesque); the latter spawned during the summer of 1938. Throughout the growing season of 1939, fish were removed at the rate of about 25 pounds per acre per month. The percentage of fish of desirable sizes was greatly increased after one year as a result of the practices set up.

This improvement was accomplished without additional stocking, without the construction of spawning beds, without forage fish, without the planting of aquatic vegetation, without fertilization and without the addition of brush piles.

Illustrations covering certain phases of our study on Fork Lake are shown in plate 1.

ACKNOWLEDGMENTS

Mr. Paul S. Smith, owner of Fork Lake, has continued to make these investigations possible by permitting the Survey staff full use of the lake. He has also helped in many phases of the work. Dr. D. F. Hansen, Dr. C. L. Schloemer, Mr. L. A. Krumholz and Mr. F. X. Lueth of the Survey staff assisted with the fishing and the collection of data. Mr. Krumholz drew graphs or figures. Mr. Lueth made preliminary stomach analyses and assisted in the tabulation of data.

Aid in moving fish, planting trees and supervision of road construction and levee work was received from Mr. Alvin C. Tuggle of the Illinois State Department of Conservation, under the directorship of Mr. Thomas J. Lynch.

Mr. Sam A. Parr, District Inspector with the State Department of Conservation, has contributed to the completeness of this paper through collection of important field data.

SUMMARY OF THE 1939 YIELD

A total of 1,289 fish, weighing 223.4 pounds, was removed from Fork Lake during 1939. This is equivalent to 934 fish, or 162 pounds, per acre and is about half of the theoretical carrying capacity of the lake for hook-and-line fish. The catch is listed in table 1.

TABLE 1.--FISH REMOVED FROM FORK LAKE DURING 1939.

Age Group	Bluegills		Largemouth Bass	
	Weight, Pounds	Number	Weight, Pounds	Number
Breeders	57.0	162	--	--
1938 brood . . .	115.0	774	51.0	349
1939 brood . . .	0.4	4	--	--
TOTAL	172.4	940	51.0	349

This catch includes 60 per cent of the original bluegill breeders, 24 per cent of the original bass fry and an unknown percentage of the bluegills produced in the lake in 1938. It is evident that the 1938 brood of bluegills furnished the greatest part of the catch, both in numbers and in weight.

For comparison: fish stocked in the summer of 1938 consisted of 270 bluegills weighing about 40 pounds and 1,440 largemouth bass fry weighing 0.15 pound.

Other useful forms of wildlife from the lake and the area around it were taken during the year. Eight snapping turtles weighing 69.4 pounds and 31 painted turtles weighing 29.2 pounds, were removed as well as five bullfrogs, *Rana catesbiana*, weighing 1.6 pounds. During the trapping season, 14 muskrats were caught in steel traps set around the edge of the lake.

Mr. Smith owns 60 acres of land surrounding Fork Lake. Part of this land is planted as an apple and nut orchard and grape arbor. Other parts are in sweet clover and blue grass. A woodlot of 30 acres lies east of the lake. Cover is good over most of the area. A wildlife food patch of small grains is planted each spring. During the 1939 hunting season, 49 quail and 134 rabbits were killed on this area by hunters.

FISH OF DESIRABLE SIZE

Legal lengths of fishes, as listed in the Illinois fish code, are set to improve hook-and-line fishing. Where there is little danger of exterminating a species, these lengths should be small to enable sportsmen to control large, stunted populations by hook-and-line fishing. Our term "desirable size" relates to sport and table use and in a number of instances is larger than the legal size.

Among the pan, or fine, fishes the minimum size for sport or table use should be at least 0.2 pound. Converted into total lengths, this weight is about 6 inches for bluegills and other sunfish, 7 inches for bullheads, 7 or 8 inches for crappies and 10 inches for channel cat. The minimum legal length for the largemouth bass is 10 inches, and a fish of this size weighs a little over one-half pound.

When poison was applied to Fork Lake in June, 1938, there were only 97 hook-and-line fish of desirable sizes, with a total weight of 32.4 pounds. These amounted to 1.8 per cent of the total number and 4.3 per cent of the total weight of fish in the lake. Table 2 itemizes the desirable fish population at the time of poisoning, which is in contrast to the population of the lake in 1939 when late in the season all of the bluegills, except the newly spawned 1939 brood, were large enough to offer sport (0.2 pound or larger). Of all fish taken in 1939, 39.2 per cent were of desirable sizes.

TABLE 2.--HOOK-AND-LINE FISH OF DESIRABLE SIZES IN FORK LAKE, JUNE 7, 1938, AT THE TIME OF POISONING.

Desirable Length, Inches	Kind	Number	Total Weight, Pounds
10*	Largemouth bass.	5	8.06
8	White crappie.	16	6.28
6	Warmouth bass.	5	1.25
6	Bluegill	11	2.45
6	Green sunfish.	24	3.84
10	Channel catfish.	4	4.56
7	Black bullhead	32	5.97
	TOTAL	97	32.41
	PER ACRE	70	23.49

*Legal length.

FISH LENGTHS IN 1939

The largemouth bass taken in 1939 were of widely different sizes. According to Cooper (1936) and others, this variability is the result of cannibalism in some of the population; a rapid increase in size takes place among a few individuals which begin a fish diet at an early age. These larger individuals were caught more readily than the smaller fish and made up the greater part of the early collections. Table 3 shows the numbers of bass of different lengths, by months.

TABLE 3.--LENGTH DISTRIBUTION OF THE 1938 BROOD LARGEMOUTH BASS TAKEN FROM FORK LAKE DURING 1939

Total Length, Inches	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
4	..	..	..	..	..	..	..	..	..
½	..	..	1	..	..	..	..	..	..
5	10	1	14	..	..	..	..	..	..
½	3	..	74	12	..	..	..	..	..
6	2	..	9	17	4	4	..	..	..
½	1	..	9	2	3	14	21	3	2
7	5	2	8	2	..	4	34	5	9
½	3	3	9	3	..	..	7	3	..
8	3	4	4	1	..	1	..	1	..
½	..	12	1	2	..	..	..	1	..
9	..	8	1	1	1	..	..	1	..
½	..	1	1	..	..	..	..	..	..
Legal length									
10	..	..	..	..	..	..	..	..	..
½	..	..	..	..	..	1	..	..	..
11	..	..	..	..	..	1	1	..	..
½	..	..	..	..	..	..	..	..	..
TOTAL	27	31	131	40	8	25	63	14	11

In April and May, two bass 9.5 inches long were taken which might have reached legal length (10 inches) by June. After June, the average size of the bass collected was smaller than earlier in the season. Exceptions were three fish, 10.5 and 11 inches long, taken in August and September. These fish probably reached the legal length of 10 inches at 13 to 14 months. Most of the bass captured late in the summer were between 6.5 and 7.5 inches.

TABLE 4.--LENGTH DISTRIBUTION OF BLUEGILLS TAKEN FROM FORK LAKE DURING 1939.

Total Length, Inches	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
2	1								
½	4								
3	5	1938 Brood							
½	6			1					
4	12	18		1	1			1939 Brood	
½	4	14	5	12	5	1	3		
5	1	5	16	73	43	14	3	1	
½			3	74	36	14	53	6	2 1
6				13	28	36	94	38	14
½					3	9	38	27	5
7	2	21	1	10	7	3	9	16	7
½	2	26	10	18	7	1	9	2	
8	1	20	3	6	1	1	8	1	1
½		3	1	Original Breeders					
9									
TOTAL	38	107	39	208	131	79	217	91	30

The numbers of bluegills of different lengths are shown in table 4. In this table, the three groups--original breeders, 1938 brood and 1939 brood--are separated. The range of lengths in the 1938 brood was much greater in March than in April and May. Small individuals did not appear in the collections of the last two months, presumably because they had been eaten by the bass; the increase in average size between March and April is not entirely due to growth.

Fig. 1 shows the growth of the 1938 brood and the original breeders during 1939. The sexes are shown separately.

The original breeder bluegills grew rapidly in 1938, perhaps because they did not have to compete with other large fish. During 1939 they grew scarcely at all. At this time they were competing for the same kinds of food with active young fish nearly as large as themselves. During 1939, the yearling bluegills showed substantial growth from month to month until late October, when growth stopped completely. By this time the water temperature, recorded at 3 feet, had dropped from 58 to 45 degrees F.

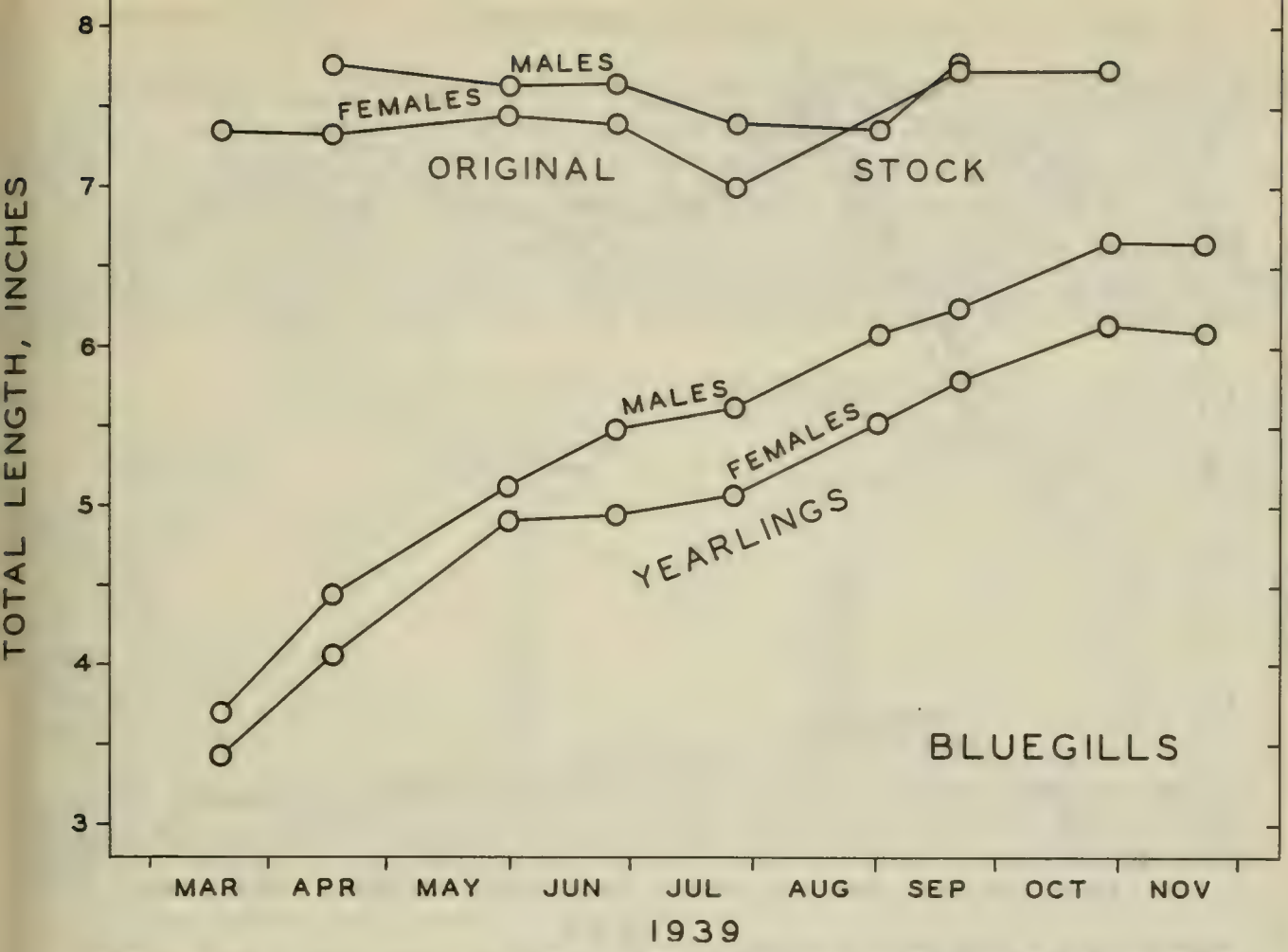


FIG. 1.--Average total lengths of bluegills taken each month from Fork Lake, 1939.

INDEX OF CONDITION

The index of condition, suggested as a practical measure of the relative plumpness of fish (Thompson & Bennett 1939b), was applied to the fish collected from Fork Lake. In general, the bluegills were in exceptionally good condition, with much fat around the digestive organs. On the other hand, the condition of the bass was near the average for this fish in other Illinois waters.

The largemouth bass and the bluegill, as well as most other members of the sunfish family, tend to grow in width and thickness faster than they grow in length. This means that the index of condition increases with length. In the bluegills, the males had a greater index than the females because of their greater length. Table 5 shows the average index of condition of the fish taken from Fork Lake.

TABLE 5.--AVERAGE INDEX OF CONDITION, "C," OF LARGEMOUTH BASS AND BLUEGILLS TAKEN FROM FORK LAKE, MARCH THROUGH NOVEMBER, 1939.

Month	Bluegills, Original Breeders		Bluegills, 1938 Brood		Largemouth Bass	
	Number	"C"	Number	"C"	Number	"C"
March	5	8.24	29	6.10	27	4.31
April	69	8.66	35	6.84	38	4.75
May	15	8.98	24	8.81	131	4.72
June	18	8.18	96	8.16	32	4.64
July	15	7.98	141	8.17	9	4.50
August	6	8.26	48	8.89	28	4.49
September	13	8.60	197	8.16	43	4.29
October	3	8.22	86	8.23	14	4.37
November	1	7.71	29	8.00	11	3.99

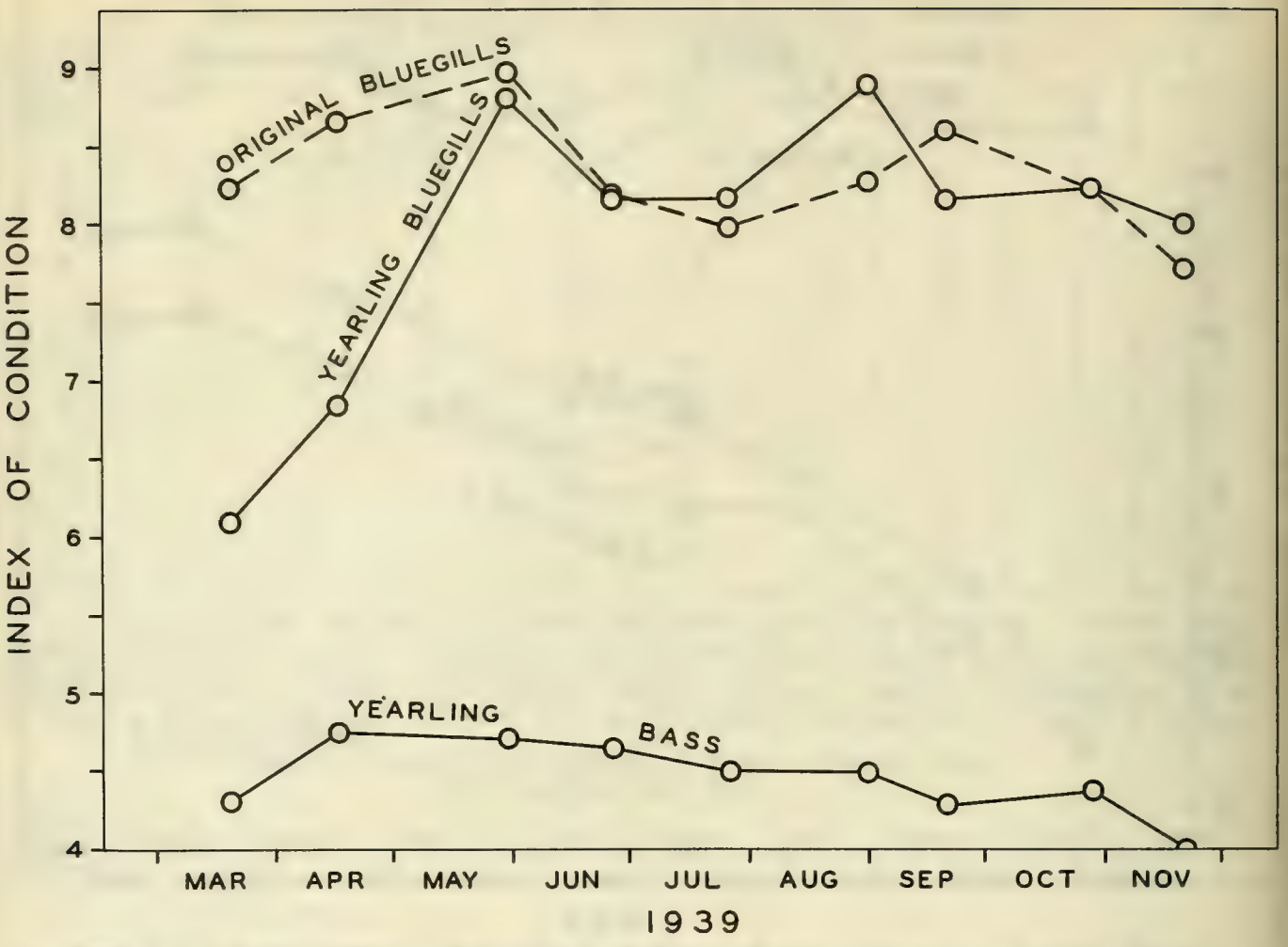


FIG. 2.--Average indices of condition of bass and bluegills taken at Fork Lake throughout the collecting season of 1939.

The fluctuations in the indices of condition listed in table 5 are diagramed in fig. 2. The bluegills were heaviest just before spawning, but lost weight rapidly during the prolonged spawning period, from early June to late August. It may be of some significance that the bass, which did not spawn, had about the same index of condition throughout the year.

Dr. Donald F. Hansen (unpublished manuscript) has followed the change of condition of Lake Decatur crappies for a number of years. Among sexually mature fish, he has found condition highest during December and January. In spring the condition decreases rapidly and is lowest in June and July, when the fish spawn.

Although Fork Lake bluegills showed a decline in condition during the spawning season, this decline did not begin until June, and there is no indication from the November collection that the greatest plumpness is in the winter. These differences in the time of change in condition may be characteristic of the two species.

FISH PARASITES

Dr. Lyle J. Thomas of the Department of Zoology, University of Illinois, found that both bass and bluegills from Fork Lake contained large numbers of cysts of the tapeworm *Ophiotaenia* sp. Other stages in the development of this parasite are found in copepods and in the water snake, *Natrix sipedon*.

The nematode, *Spinetectus* sp., was also found in these fish. It is probable that other stages of this parasite are borne by some aquatic insect (Mayfly or stonefly).

We believe that these parasites have had little effect on the growth of the fish in Fork Lake.

TIME OF ANNULUS FORMATION

The fish of Fork Lake offered unusual opportunities to study the time of annulus formation. All bass were known to have been spawned in June, 1938, and the bluegills, until midsummer, could be separated with certainty into two distinct groups, namely, original breeders and the 1938 brood spawned in Fork Lake. Toward the end of the season a few small, 1939 bluegills appeared in the nets. In the 1938 broods of bass and bluegills, the actual ages were known, and in March, 1939, the scales of the fish collected were free from any marks that might be interpreted as annuli. Collections were taken at monthly intervals, March through November, making it possible to measure accurately when annuli were formed. Table 6 shows the percentages of the collected fish having new annuli. These percentages are shown also in fig. 3. The midpoints of annulus formation as read from the graphs were the following dates: May 4 for yearling bluegills, May 16 for breeder bluegills, June 9 for yearling bass.

TABLE 6.--PERCENTAGE OF FISH WITH NEW ANNUAL RINGS.

Date of Collections	Largemouth Bass, 1938 Brood	Bluegills	
		1938 Brood	Original Breeders
March 18-24	0	0	0
April 13-18	11	16	1
May 29-30	37	100	73
June 16-30.	71	100	78
July 25-August 3. . . .	100	100	87
August 28-September 8 .	93	100	100
September 18-22	95	100	92
October 27-30	100	100	100
November 17-24.	100	100	100

Among the yearling bluegills, growth was both rapid and uniform throughout the growing season of 1939, fig. 1. In a few individuals, annulus formation took place before April 18, fig. 3, and in all of the fish collected annuli were visible at the end of May. All yearling bluegills collected had formed annuli by the time nest building and spawning began.

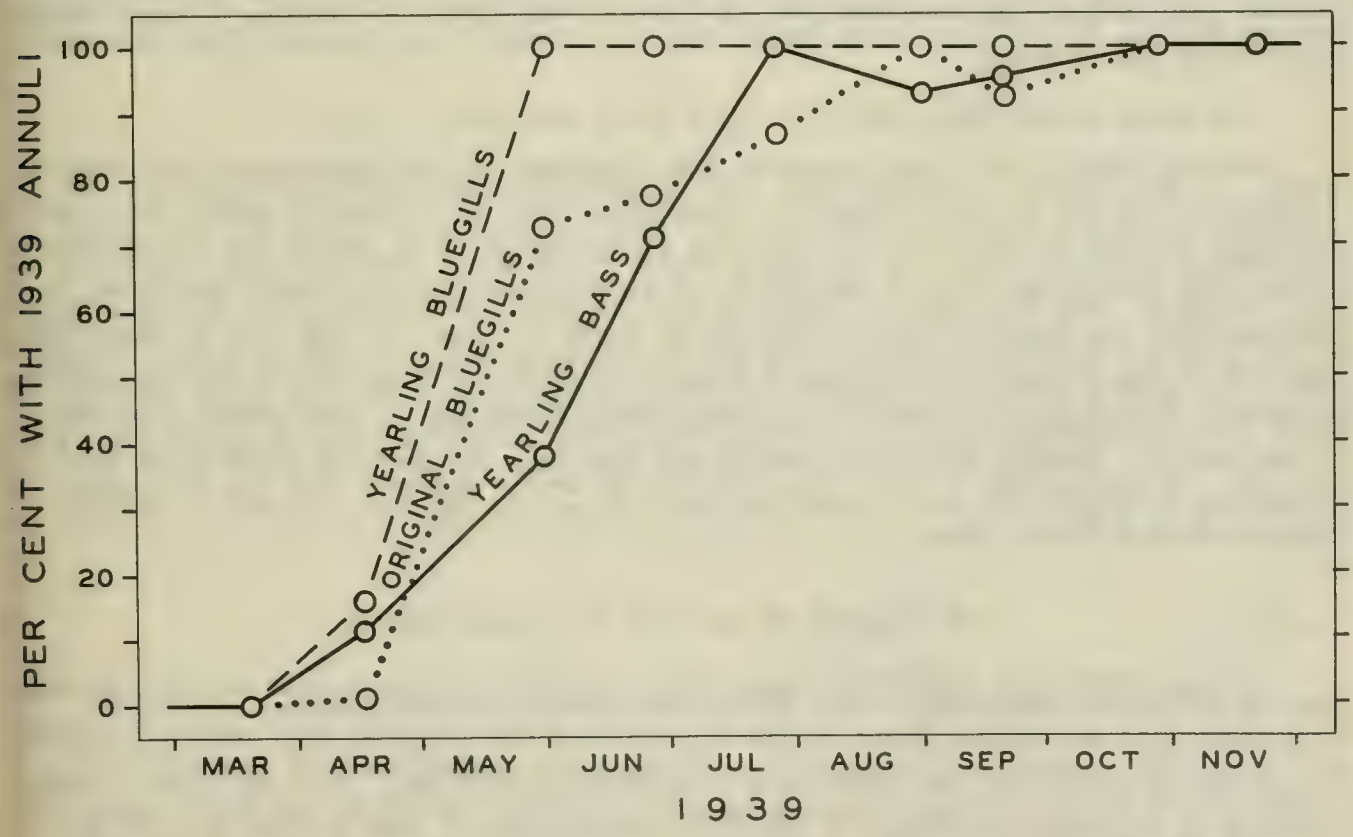


FIG. 3.--The formation of the 1939 annuli in bass and bluegills taken from Fork Lake, March-November, 1939.

The 1938 brood of bass grew rapidly in 1938, but slowly in 1939 (discussed later). In these bass collected from Fork Lake, annulus formation extended from mid April to late September, fig. 3. However, only a few had failed to form annuli by the end of July. These were large fish showing marked erosion on the anterio-lateral angles of the scales (plate 2B) and other evidences of starvation (James 1939).

It may be that the yearling bluegills formed their annuli within a month, and the yearling bass formed annuli over several months, because the former were well fed and growing rapidly, while the latter were partially starved. See plate 4 for comparison.

The original breeder bluegills made little growth in 1939. In them, annulus formation began later than in the yearlings and was not completed until fall. Delayed annulus formation in these old fish is consistent with the observations of Hansen (1937) on white crappies in Lake Decatur, and of Thompson & Bennett (1939b) on Lincoln Lakes bass.

In the 1938 broods of bass and bluegills, a number of fish formed one or two additional or false annuli during the latter part of the summer (plates 2 and 3). False annuli appeared in the scales of some of the bluegills collected June 16-30, 1939, as indicated in fig. 4, and were found in increasing proportions until September or October. Twenty-four per cent of the yearling bluegills taken after June 16 had these supernumerary annuli. False annuli were not found on the largemouth bass scales until August, fig. 5, but were present in all later collections in increasing proportions, appearing in 38 per cent of all bass collected after the first false annulus in this species was found. Evidences of second false annuli in the yearling bluegills were first observed in July; individuals with second false annuli apparently did not exceed 5 per cent of all the yearling bluegills collected after the appearance of the annuli. In the bass, third annuli had formed in a few individuals taken in the November collection.

From the time false annuli were first found in the bass until fishing ended in November, about 6 per cent of these fish collected showed supernumerary annuli that fulfilled all the criteria of true annuli in the hands of an experienced scale reader using the most critical techniques. About 10 per cent of the bluegills taken after June 16 showed supernumerary annuli that could not be distinguished from true annuli. In fact, some of the additional rings fulfilled the description of annuli better than the first rings (plates 2 and 3). These percentages, 6 for the bass and 10 for the bluegills, give a measure of the probable error of age determination, had the actual ages not been known. In the cases in which the false annuli fulfilled all the known requirements of true annuli, there was distinct "cutting over" across the circuli in the posterior field, and the false annuli did not tend to join the true annuli in the lateral and posterior fields. In many scales, spacing between the true and false annuli was wide enough to be interpreted as representing a whole year's growth.

Both sexes showed false annuli in about equal numbers.

Hubbs & Cooper (1935) have suggested that supernumerary or false annuli are spawning marks. In the material described here this suggestion might conceivably apply for the false annuli of the yearling bluegills, since these fish had a spawning season that corresponded roughly to the period in which the percentage of false annuli was increasing. However, it could not apply for the false annuli found in the yearling bass, which did not spawn. The percentages of true annuli and of first or second false annuli are shown in figs. 4 and 5. The false annuli described here in both bass and bluegills should not be confused with the spawning checks described by Hubbs & Cooper. At the time of their publication it was generally accepted that the Centrarchids formed annuli in winter. Since that time, Hansen (1937) and Thompson & Bennett (1939b) have shown that white crappies and largemouth bass form their annuli from late spring to autumn. It now appears that what Hubbs & Cooper interpreted as the spawning check (the inside member of a double ring) was a true annulus, whereas the outside member may have been the spawning check which they discuss. An examination of their illustrations of scales suggests that the fish were increasing in length and not in girth, thereby elongating the scale pockets to produce their so-called double rings.

THE RELATION OF BODY AND SCALE MEASUREMENTS

Creaser (1926) and others have shown that the scales of fishes grow at about the same rate as the fishes themselves. This is because fish have the same number of scales throughout life and because these scales are arranged like shingles on a roof and tend to grow just fast enough to cover the body. Consequently, measurements of the growth of scales can be translated into measurements of growth of the fish. In some kinds of fish, growth of the scales is almost exactly proportional to the growth of the fish, making it possible to calculate the length of the fish corresponding to that portion of a scale designated by any point or mark on the scale. The annual ring is an example of such a mark. Proportional growth of body and scales seems to prevail in the largemouth bass.

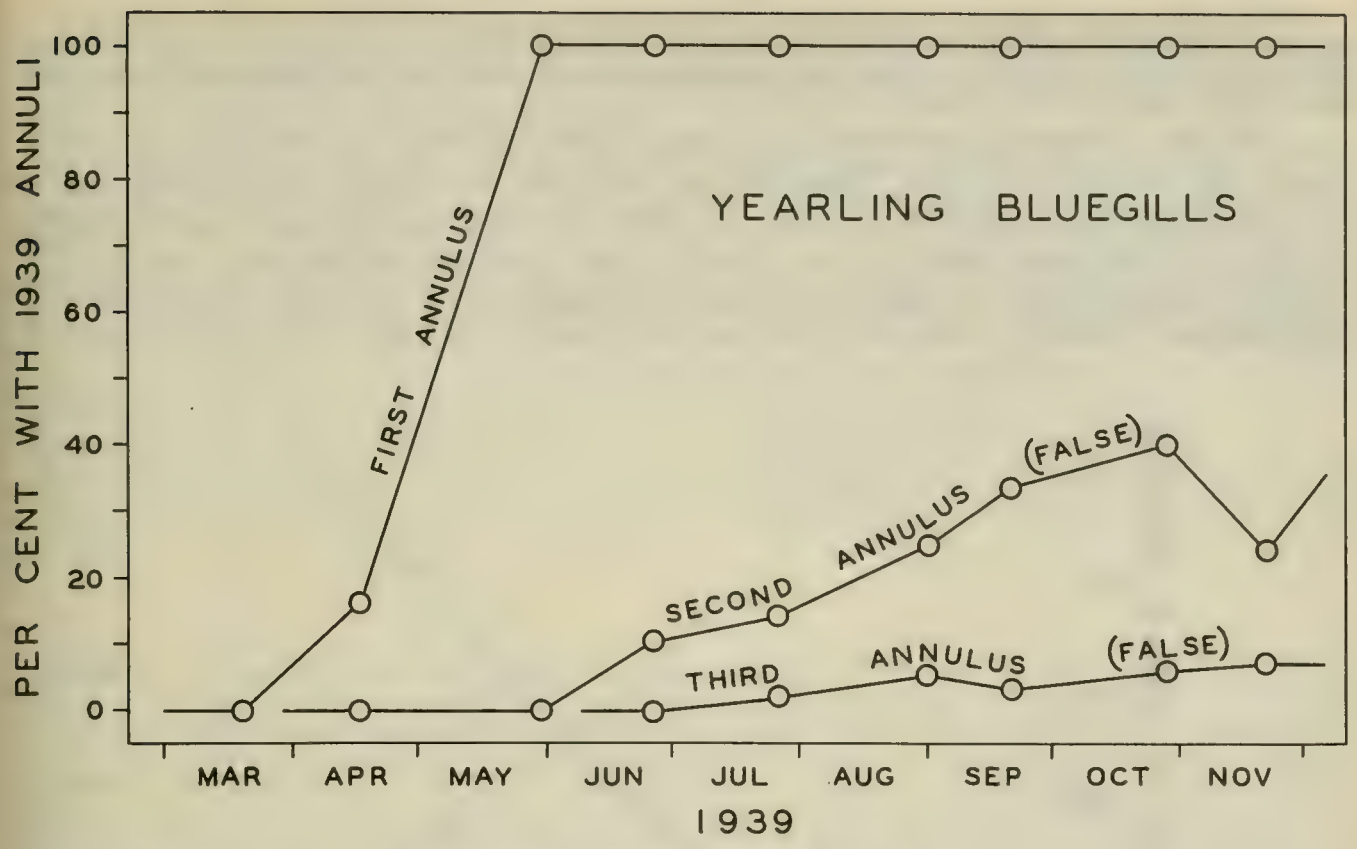


FIG. 4.--Formation of second and third annuli (false) in yearling bluegills taken from Fork Lake, 1939.

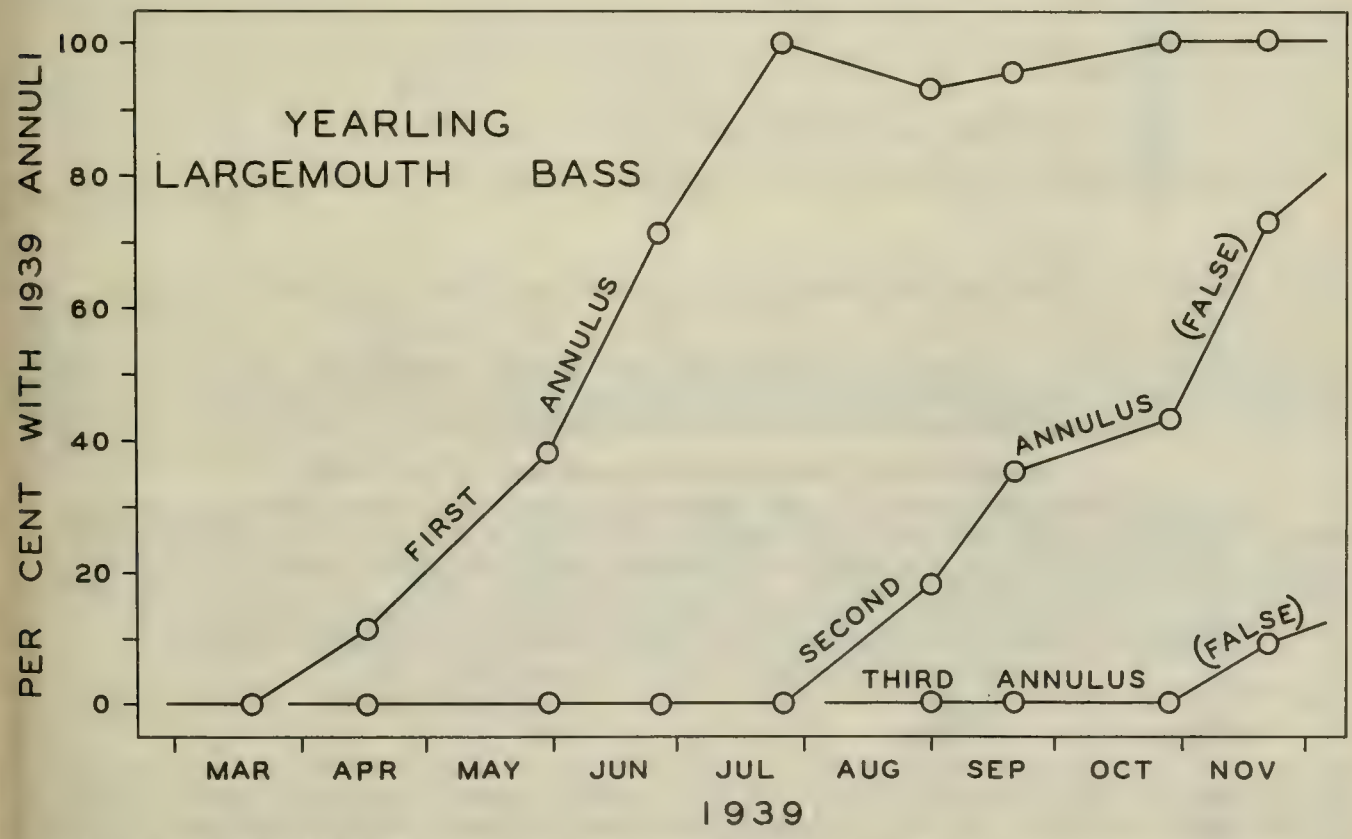


FIG. 5.--Formation of second and third annuli (false) in yearling largemouth bass taken from Fork Lake, 1939.

In other fish, such as the bluegill, the scales overlap each other more at certain times in the life of the fish than at others. In these fish, it is necessary to correct the body lengths calculated from scale measurements in order to obtain a close approximation of the actual body lengths.

The most convenient measurement of a scale is the distance from the focus, or center of the scale, to the anterior edge. Scales from the side of the fish a little below the dorsal fin are uniform in size. These are the ones that are used in making comparisons of scale measurements and lengths of fish. In bass, the anterior radii of these scales seem to be directly proportional to the total length of the fish for all sizes from fingerlings up, fig. 6. When measurements of the anterior radii of scales against total lengths of bluegills are plotted, the result is not a straight line, as in the bass, but one that is slightly S-shaped, fig. 7. When the lengths of bluegills were calculated from scale measurements, a smoothed curve was drawn and body lengths were read directly from the curve.

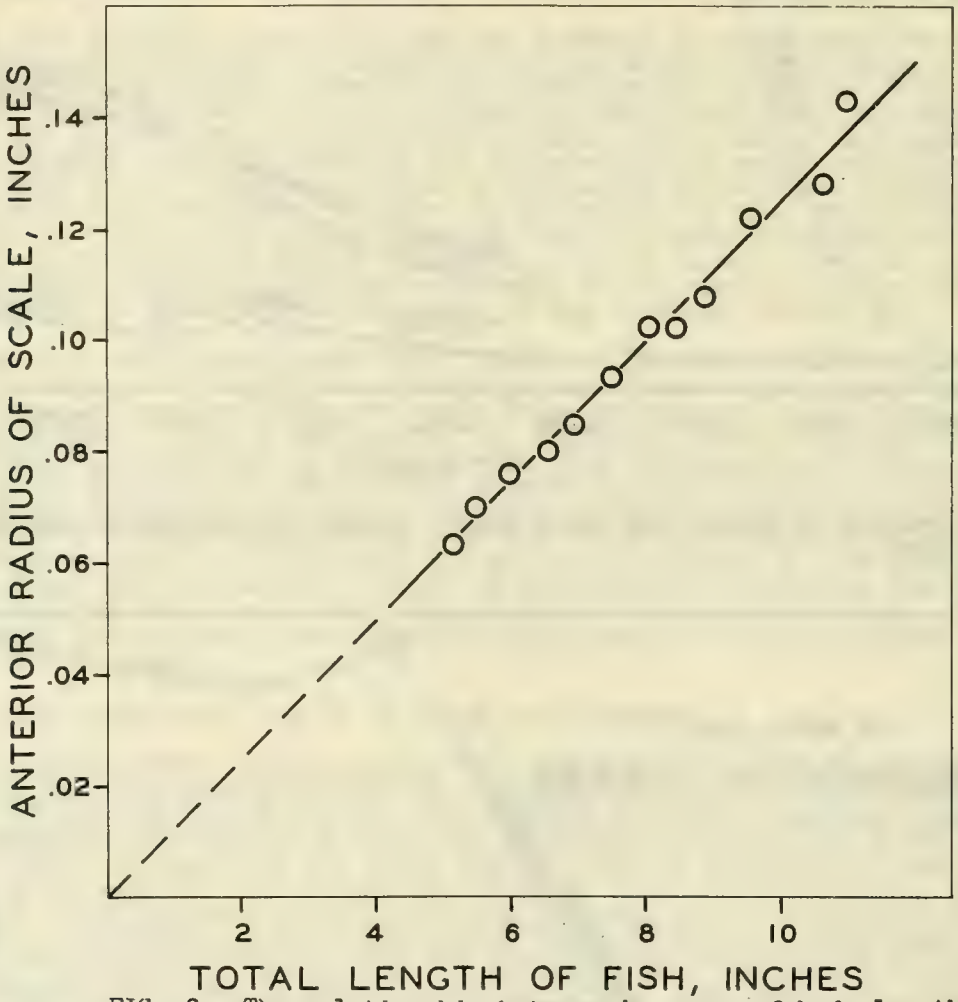


FIG. 6.--The relationship between increase of body length and anterior radius of scales in largemouth bass.

COMPARISON OF THE GROWTH OF BLUEGILLS IN TWO LAKES

The breeder bluegills of Fork Lake spent their life, until 1938, in Homewood Lake, where they were crowded and forced to compete with a dense population of fish of other kinds. Age determinations and growth measurements made from their scales allow us to compare the growth in these two small lakes of a number of these fish collected in 1939.

TABLE 7.--AVERAGE CALCULATED TOTAL LENGTHS OF ORIGINAL BREEDER BLUEGILLS IN HOMEWOOD LAKE AND AVERAGE MEASURED TOTAL LENGTHS (UNDERSCORED FIGURES) AFTER THE FISH HAD SPENT A YEAR IN FORK LAKE.

Year Spawned	Number of Fish	Age in Years					
		1	2	3	4	5	6
1933	5	2.16	3.53	4.36	5.03	5.79	7.62
1934	21	2.61	3.94	4.93	5.71	7.49	....
1935	72	2.60	4.31	5.49	7.52	....	....
1936	54	3.37	5.11	7.51	....	....	....

Table 7 shows average calculated total lengths of these original breeder bluegills for each year of life. Their average measured total lengths when taken from Fork Lake in 1939 are underscored. It will be noted that each brood showed unusually large growth during the year they spent in Fork Lake. The average increase in length of these fish during this time was about 2 inches for all ages.

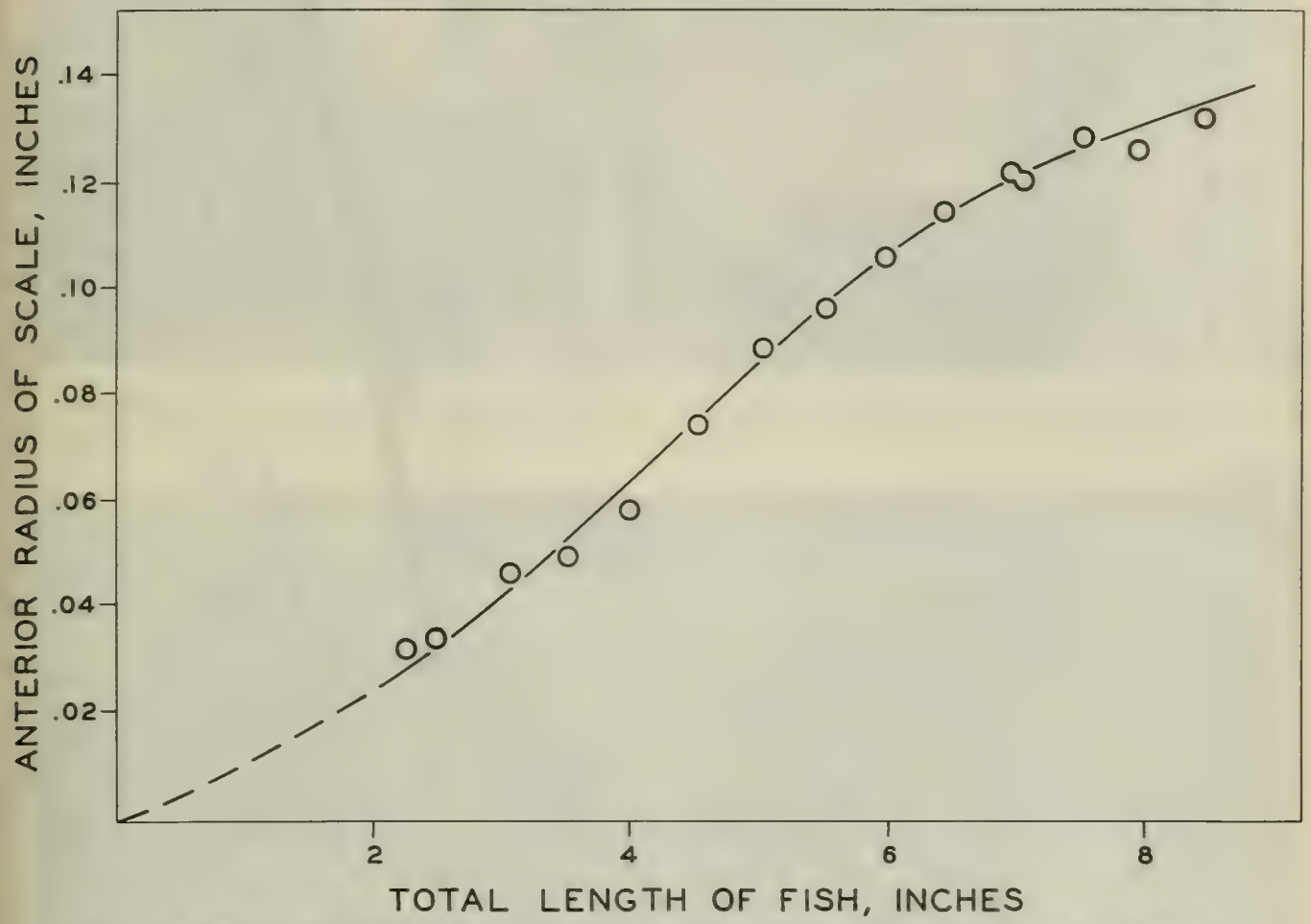


FIG. 7.--The relationship between increase of body length and anterior radius of scales in bluegills.

Growth in weight is a better measure of fish production than growth in length, especially when fish of different sizes are being compared. The breeder bluegill lengths shown in table 7 have been translated into weights to show the relative growth in these fish while in Homewood Lake and in Fork Lake. Average weights for each brood at the end of each year of life are shown in fig. 8. Average actual weights were used for these breeder bluegills after their year in Fork Lake. Calculated lengths for earlier years were translated into calculated weights by using average indices of condition for Homewood Lake bluebills, as shown in table 8.

TABLE 8.--AVERAGE INDICES OF CONDITION, "C," FOR HOMEWOOD LAKE BLUEGILLS, JUNE, 1938.

Total Length, Inches	Average "C"
2-3	4.0
3-4	5.0
4-5	6.0
5-6	7.0

Additional comparison is furnished in fig. 8 by including the average weights of the 1938 brood of bluegills at three seasons during 1939. It will be noted that these yearling bluegills from Fork Lake averaged larger than fish ranging from 2 to 5 years old from Homewood Lake.

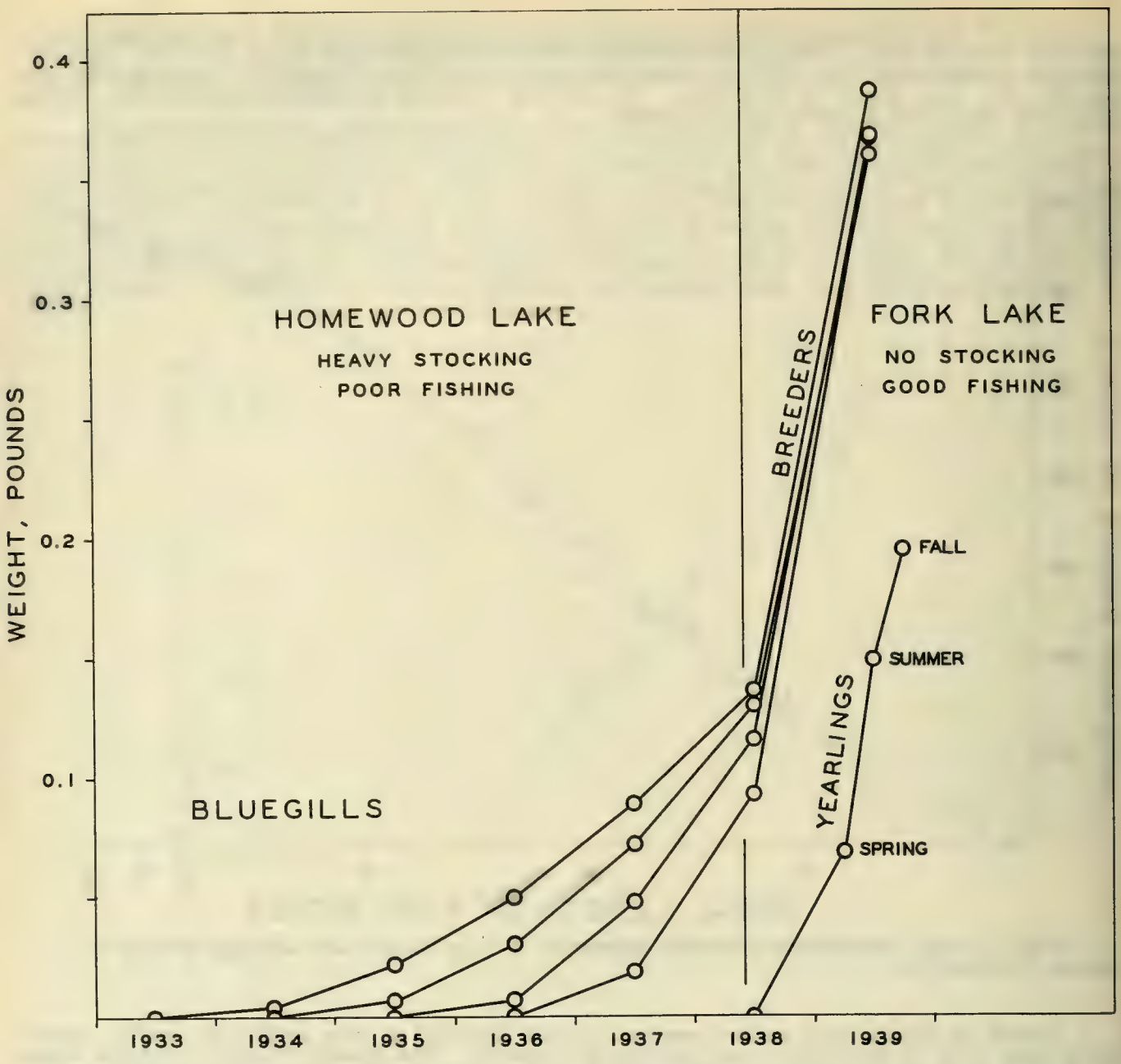


FIG. 8.--Increase in weight of bluegills in Homewood Lake under conditions causing stunting, and increase in Fork Lake under optimum conditions. The growth of the 1938 brood bluegills, spawned in Fork Lake, is shown through 1938 and 1939.

LIMNOLOGICAL OBSERVATIONS

Limnological observations on Fork Lake for 1939 included a continuous record of water temperatures at a depth of about 3 feet with a Friez recording thermograph, plate 1; transparency readings made with a standard Secchi disc; and water levels read at weekly intervals or oftener. These records have been compared with average weekly maximum and minimum air temperatures and rainfall, recorded at the Decatur weather station, about 6 miles from Mount Zion. Frequently, vertical temperature sections were taken with a reversing thermometer. Records were begun the first week in March, after all the ice of the lake had melted.

Rainfall, transparency and water level readings are listed in table 9. In table 10, maximum and minimum weekly air temperatures are listed, together with average water temperatures. In fig. 9, these physical data are summarized in a single illustration. At the top of this figure are shown the average weekly maximum and minimum air temperatures and their relation to average water temperatures. The difference between these maximum and minimum air temperatures for any week is 20 to 30 degrees F., with the water temper-

Recording thermograph, protected by bullet-proof shield (on post), mail box and iron pipe; used in making continuous water temperature record.

Gage board, attached to iron fence posts driven into the lake bottom, set up in March, 1938, to be used for measuring water levels.

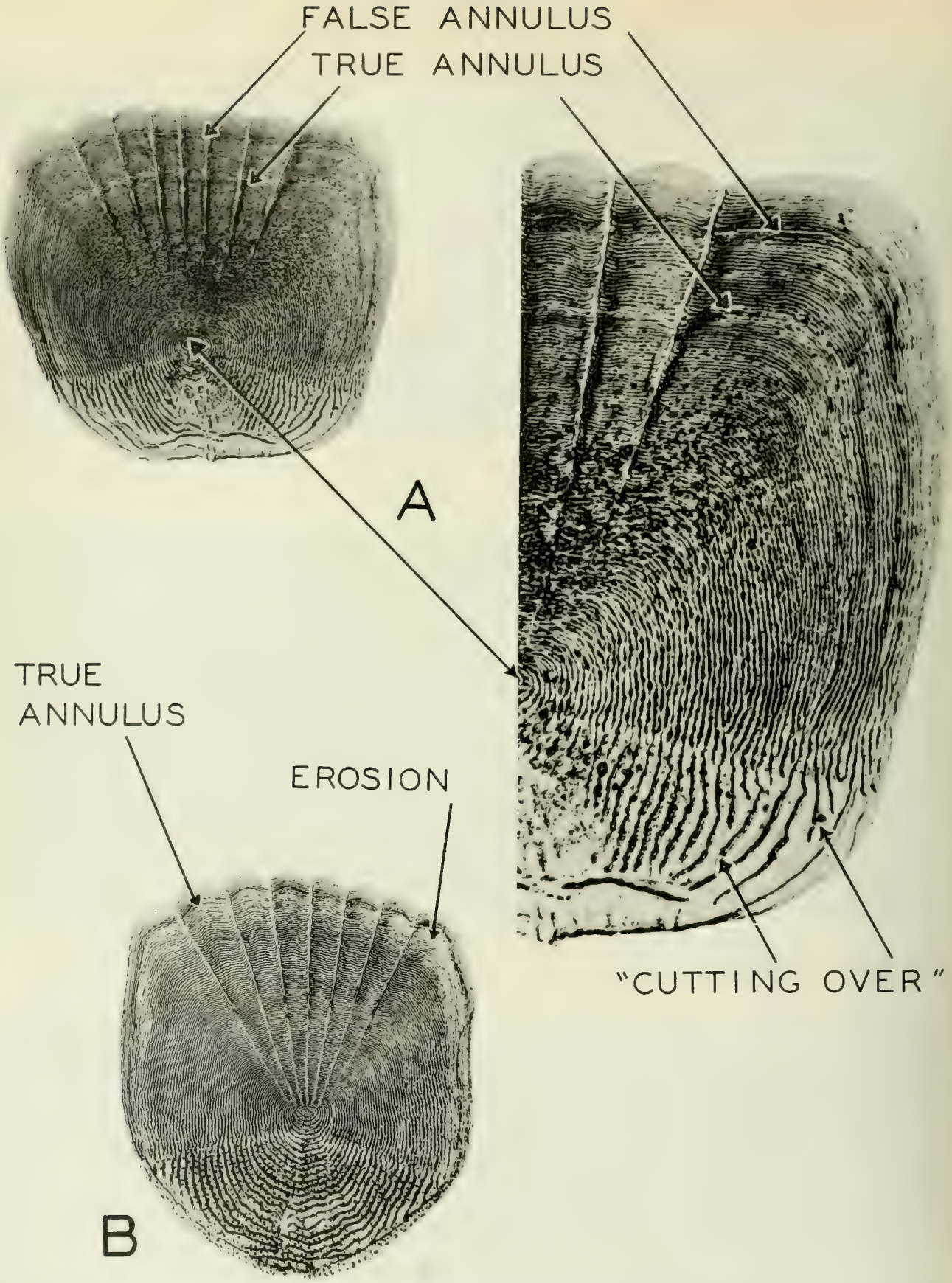
Tame rice, planted to provide grain for wildlife, was seriously damaged by muskrats, July, 1939.

Broken concrete held in place by heavy woven-wire fencing protects the levee from crayfish and muskrats.

Inexpensive spillway suitable for small lakes with limited drainage areas.

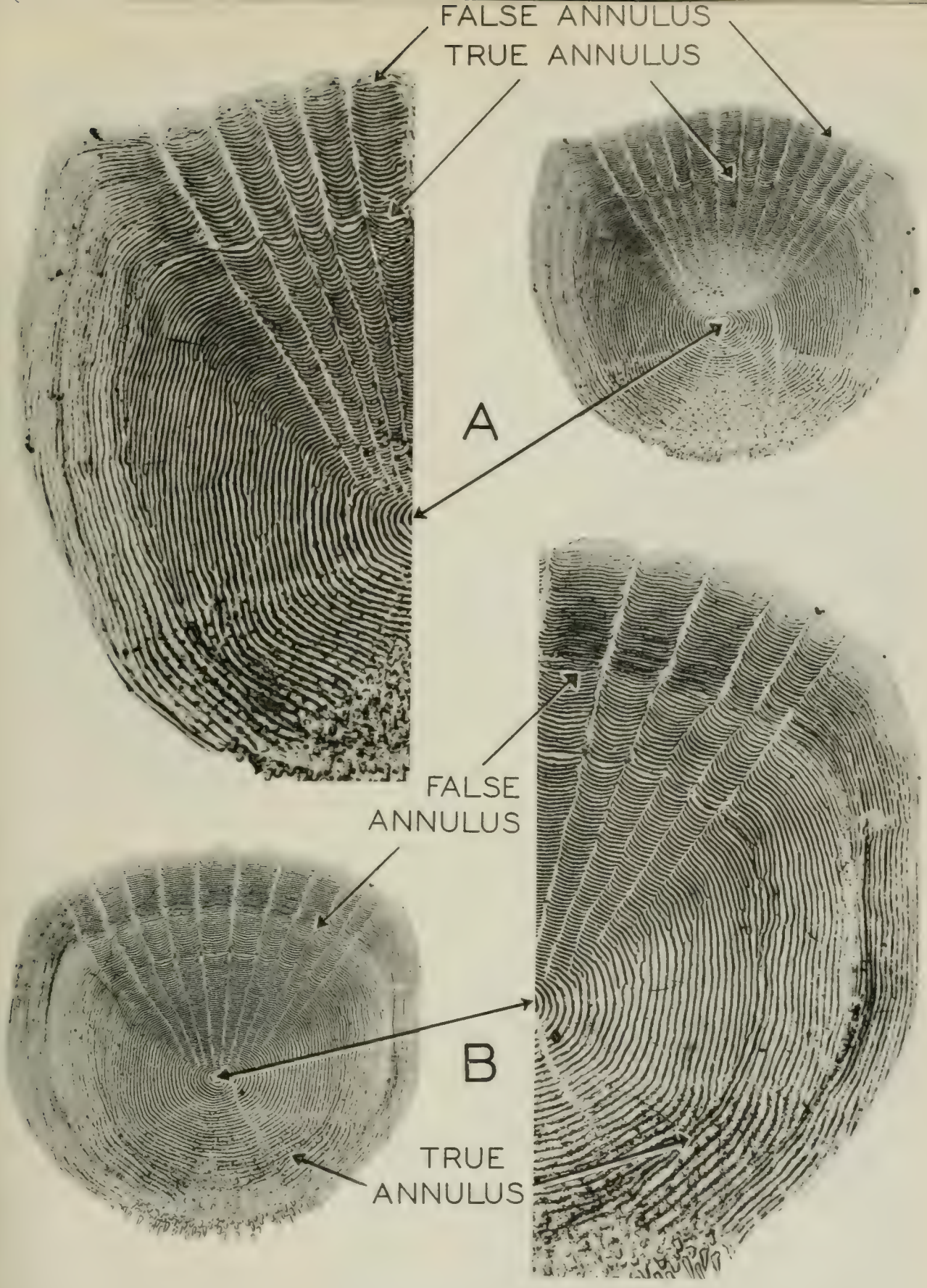
Bluegill nests left exposed by low water in Fork Lake, September, 1939.

PLATE 1



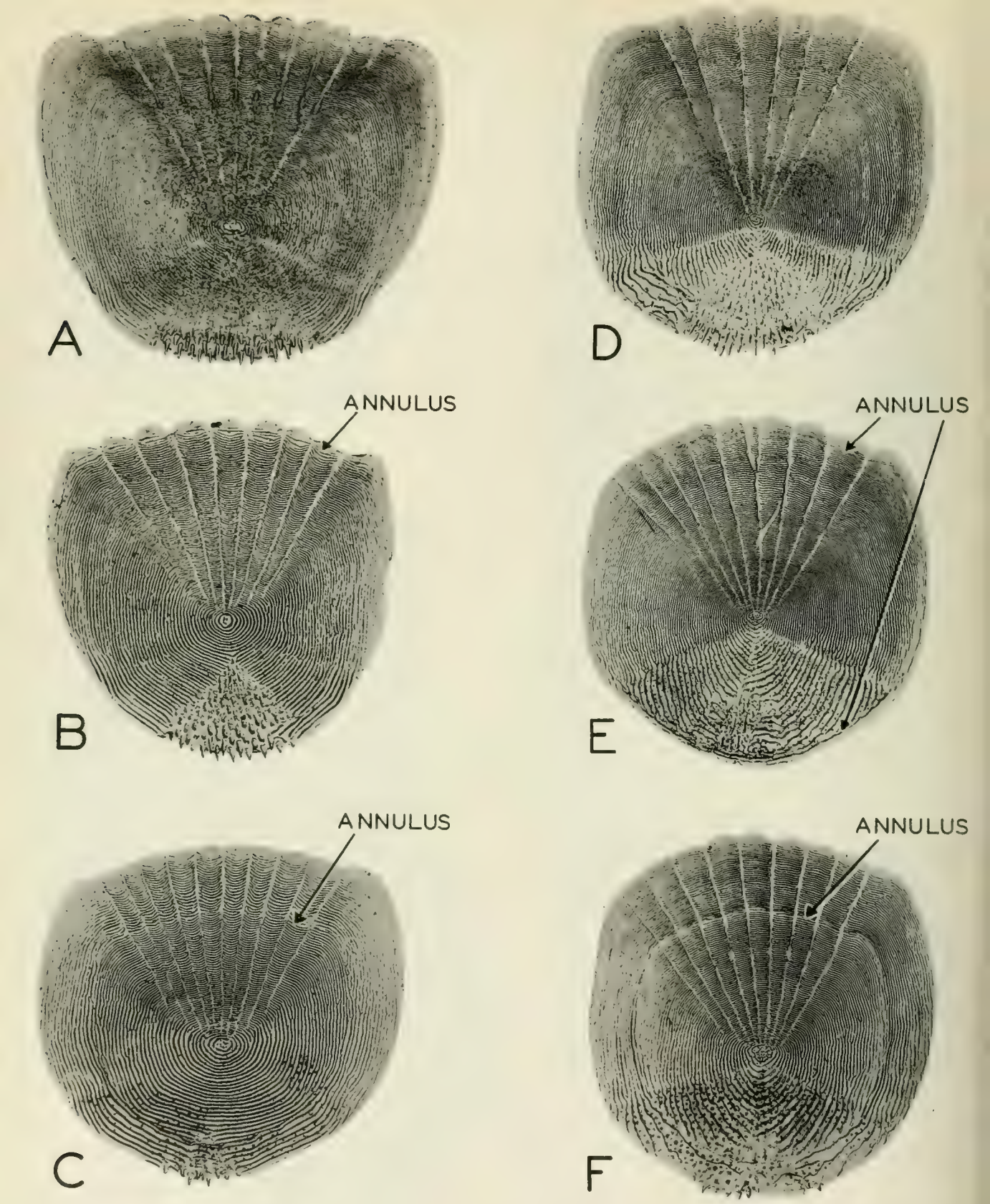
A. Scale of a yearling largemouth bass showing well-defined true and false annuli. Both rings show "cutting over" in the posterior field and are clearly separated throughout. The false annulus might be discarded by some workers because it lies fairly close to the true annulus; fish caught September 20, 1939; age, 16 months. B. Scale of a yearling largemouth bass, caught October 30, 1939; age, 17 months. This scale indicates that the fish grew very rapidly in 1938 (clear circuli throughout most of large scale), but very slowly in 1939 (erosion on anterior and lateral edges of scale), and that the annulus was formed very late in the summer (narrow band of growth showing no erosion outside of the annulus).

PLATE 2



A. Scale of yearling bluegill showing true annulus, and false annulus forming on the edge; fish caught July 25, 1939; age, 14 months.
B. Scale of a yearling bluegill caught on September 22, 1939, age, 16 months, showing well-defined true and false annuli.

PLATE 3



Annulus formation in yearling bluegills (A, B, C) and yearling largemouth bass (D, E, F). A. Scale of bluegill, 4.2 inches, showing some indication of annulus formation; fish caught April 17, 1939; age, about 11 months. B. Scale of bluegill, 4.4 inches, showing annulus in only the anterior field; fish caught April 17, 1939; age, about 11 months. C. Scale of bluegill, 4.8 inches, showing annulus surrounded by a wide margin of growth; fish caught May 30, 1939; age, 12 months. D. Scale of largemouth bass, 7.4 inches, without annulus, but showing a change of growth rate during 1938. "Cutting over" may be seen in the posterior field but the "cutting over" on the left side does not correspond with that on the right; fish caught March 18, 1939; age, 10 months. E. Annulus nearly complete on scale of bass 8.8 inches; fish caught May 30, 1939; age, 12 months. F. Scale of bass, 6.7 inches, with annulus surrounded by a wide margin of growth; fish caught August 28, 1939; age, 15 months.

TABLE 9.--WEEKLY AVERAGE RAINFALL, TRANSPARENCY AND WATER LEVELS, FORK LAKE, 1939.

Week Beginning	Rainfall, Inches	Secchi Disc Reading, Feet	Water Level, Feet*	Week Beginning	Rainfall, Inches	Secchi Disc Reading, Feet	Water Level, Feet*
Feb. 27 . . .	0.50	....	5.00	July 31. . . .	0.26	1.65	3.05
March 6 . . .	3.86	1.00	5.00	Aug. 7	2.55	1.19	2.93
March 13. . .	Trace	0.45	4.20	Aug. 14. . . .	1.62	2.87	3.00
March 20. . .	0.08	0.70	4.40	Aug. 21. . . .	0.67	1.40	3.24
March 27. . .	0.34	0.95	4.42	Aug. 28. . . .	0.02	2.00	3.23
April 3 . . .	0.38	1.20	4.70	Sept. 4. . . .	....	1.86	2.97
April 10. . .	2.49	1.60	4.84	Sept. 11 . . .	0.44	1.60	2.80
April 17. . .	1.13	0.50	5.05	Sept. 18 . . .	....	1.50	2.70
April 24. . .	0.31	1.20	5.00	Sept. 25 . . .	0.20	2.10	2.50
May 1	Trace	3.70	4.90	Oct. 2	0.81	2.30	2.30
May 8	0.48	4.87	4.80	Oct. 9	1.74	2.00	2.30
May 15. . . .	0.52	4.80	4.65	Oct. 16. . . .	0.01	1.75	2.25
May 22. . . .	0.47	4.20	4.65	Oct. 23. . . .	0.26	1.58	2.15
May 29. . . .	0.02	4.20	4.40	Oct. 30. . . .	0.03	1.30	2.10
June 5. . . .	1.82	3.30	4.20	Nov. 6	0.68	1.20	2.00
June 12 . . .	0.35	2.25	4.10	Nov. 13. . . .	0.26	1.30	2.00
June 19 . . .	1.72	2.20	4.10	Nov. 20. . . .	0.20	1.20	2.00
June 26 . . .	0.36	1.80	3.90	Nov. 27. . . .	0.65	1.40	1.95
July 3. . . .	1.17	2.30	3.70	Dec. 4	....	1.30	1.95
July 10 . . .	0.49	2.80	3.63	Dec. 11. . . .	Trace	1.70	1.95
July 17 . . .	0.01	2.65	3.44	Dec. 18. . . .	Trace	1.40	1.85
July 24 . . .	0.45	2.50	3.27	Dec. 24. . . .	0.73	....	1.80

*Crest of spillway is 5.00 feet.

TABLE 10.--WEEKLY AVERAGE AIR AND WATER TEMPERATURES, DEGREES F., FORK LAKE, 1939.

Week Beginning	Maximum Air Temp.	Water Temp.	Minimum Air Temp.	Week Beginning	Maximum Air Temp.	Water Temp.	Minimum Air Temp.
Feb. 27 . . .	45.7	37.9	29.6	July 31. . . .	88.0	80.5	62.4
March 6 . . .	51.3	39.9	32.3	Aug. 7	85.1	77.1	64.3
March 13. . .	50.3	39.4	24.6	Aug. 14. . . .	85.7	78.7	64.3
March 20. . .	73.0	49.0	45.1	Aug. 21. . . .	82.0	74.9	57.7
March 27. . .	53.4	47.0	39.1	Aug. 28. . . .	88.1	76.9	61.9
April 3 . . .	54.9	46.0	31.7	Sept. 4. . . .	89.1	78.2	64.9
April 10. . .	55.6	45.6	36.1	Sept. 11 . . .	94.1	78.8	65.1
April 17. . .	59.3	46.9	40.0	Sept. 18 . . .	83.7	71.8	51.0
April 24. . .	75.9	58.0	49.6	Sept. 25 . . .	77.1	65.9	47.9
May 1	74.6	61.5	46.1	Oct. 2	84.3	64.7	54.7
May 8	72.0	66.0	49.7	Oct. 9	65.9	61.9	42.9
May 15. . . .	80.3	68.7	55.7	Oct. 16. . . .	73.4	55.9	45.1
May 22. . . .	88.6	77.3	64.9	Oct. 23. . . .	70.0	58.2	46.6
May 29. . . .	84.1	77.2	62.9	Oct. 30. . . .	48.3	45.5	28.1
June 5. . . .	82.4	77.1	63.7	Nov. 6	58.0	44.4	33.1
June 12 . . .	82.3	73.9	62.0	Nov. 13. . . .	63.1	45.2	37.9
June 19 . . .	84.3	79.1	65.3	Nov. 20. . . .	42.3	41.8	32.9
June 26 . . .	86.7	82.2	64.9	Nov. 27. . . .	46.1	39.0	30.0
July 3. . . .	90.7	85.0	70.9	Dec. 4	56.3	39.1	32.3
July 10 . . .	87.0	82.3	64.7	Dec. 11. . . .	52.1	38.7	30.9
July 17 . . .	84.6	79.4	66.1	Dec. 18. . . .	44.0	36.3	28.0
July 24 . . .	88.3	82.1	66.0	Dec. 24. . . .	30.1	33.3	14.0

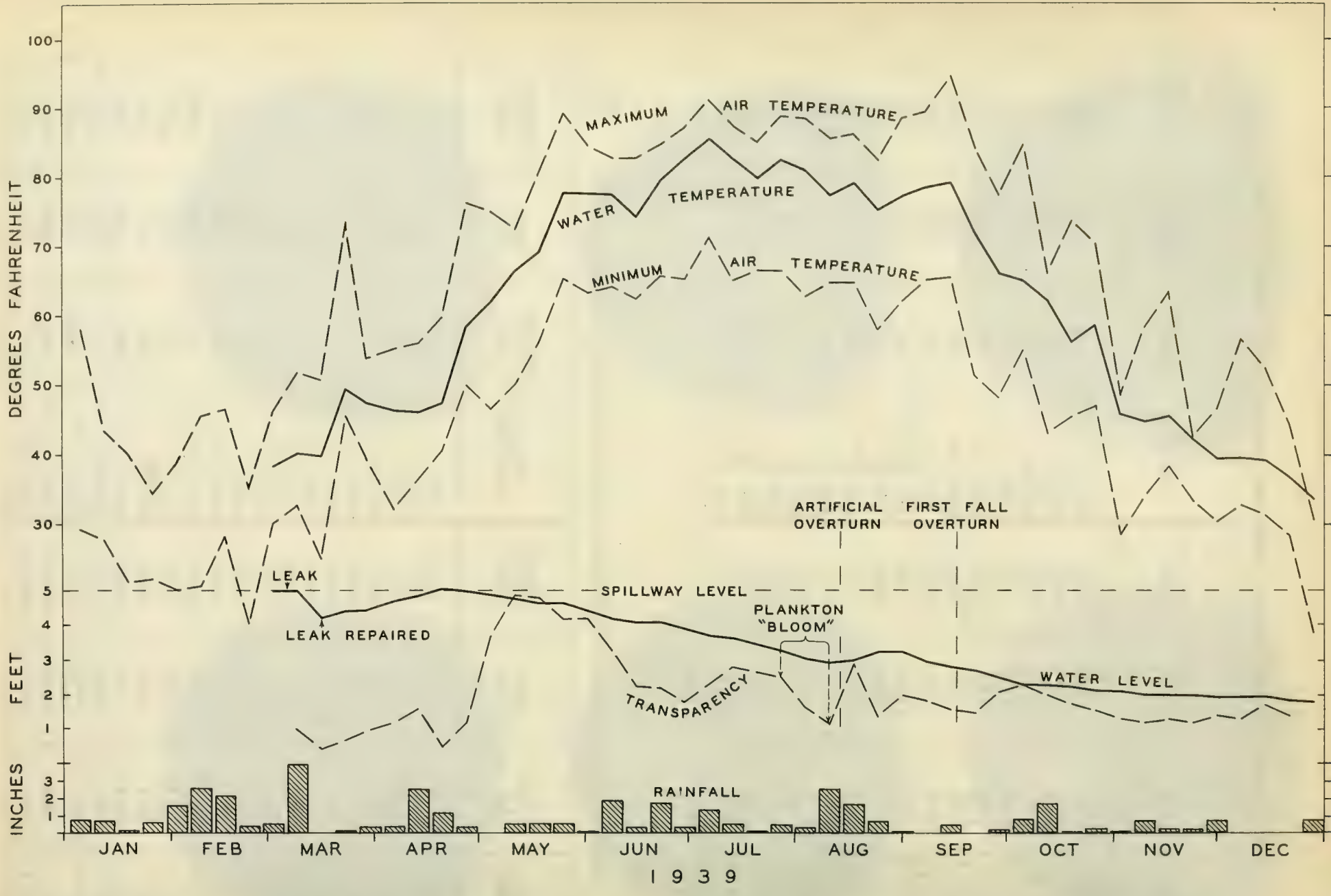


FIG. 9.--Physical conditions in Fork Lake during 1939, including air and water (at a depth of 3 feet) temperatures in degrees F., rainfall in inches (by weeks), transparency in feet and water levels in feet.

ature usually about midway between. The water temperature usually approaches the minimum air temperature in early spring and in late fall, and the maximum air temperature during summer. The water reached a maximum temperature of 85 degrees F. in the first week of July. Later, in the middle of September, when the air temperature reached its maximum for the year, the lake water was cooler than in July because of lower air temperatures during the night. The bulb of the recording thermograph was set at a depth of about 3 feet because we estimate that this is the average depth at which fish live in this lake during the growing season.

Although many things are known to affect the growth of fishes, low water temperature and a short growing season are among the most important limiting factors on the attainment of the highest possible fish production. One important reason is that fish are cold-blooded animals and cannot digest food or grow rapidly unless the water is above 55 or 60 degrees F.

Markus (1932) found that the rate of digestion in bass is very slow in water below 55 degrees F., but that it increases rapidly with increasing temperatures up to 80 or 85 degrees F. The water temperature of Fork Lake rose above 55 degrees F. during the last week in April and stayed above until the last week in October. These dates define an active growing season of 6 months in 1939. It may be noted that the average total lengths of fish taken in November were no greater than of those taken in October, fig. 1. The apparent growth of the 1938 brood of bluegills previous to the last week in April was due probably to the elimination of the smaller individuals by bass.

At the bottom of fig. 9 is shown the average rainfall in inches, by weeks. The amount and distribution of rainfall are very important since they affect both the water level and transparency. Fork Lake has a drainage area of about 60 acres, and the soil in the basin is a tight clay loam. Although erosion is well controlled, a certain amount of clay enters the lake after heavy rains. Early in 1939, the soil was saturated with water, and the rate of run-off was high. On March 1, the lake was full (5 feet on the gage board). On March 4, a small leak developed under the spillway. This leak was repaired temporarily on March 6, but water broke through again and the leak was not permanently repaired until a week later, when the water level had dropped 0.8 foot below the spillway crest. Although no more heavy rains occurred until the week of April 10, the lake level gradually rose as a result of light rains and seepage from surrounding land. Following the heavy rains of April 10-16, the lake filled and water ran over the spillway. The lake level dropped slowly but steadily throughout late spring and early summer, even though there was as much as 2 inches of rainfall per week. However, heavy rains in August raised the water 0.3 foot. After August, the water level gradually dropped to a minimum of 1.8 feet on the gage at the end of December.

Fork Lake, with about 43 acres of drainage area per acre of water surface and with average rainfall, may be expected to drop about 3 feet below the crest of the spillway in autumn.

The transparency varied from 0.45 to 4.8 feet, as measured by a Secchi disc. During the week of March 6, 3.86 inches of rain fell, and the transparency the following week was the lowest of the year. Throughout the year transparency seemed to be inversely proportional to the amount of run-off, with a lag of a few days which increased late in the summer when the ground was dry.

A dry spell the latter part of July and early August was accompanied by a "bloom" of algae which reduced the transparency. This "bloom" was composed of dinoflagellates. On August 14, the lake was stirred with an outboard motor for an hour. After a few days there was a marked increase in the transparency. Rain later in August again made the lake turbid. A severe wind storm on September 15 stirred the lake completely and was followed after 3 days by an increase in transparency due to the reduction in plankton caused by the disturbance of summer stratification.

Eleven vertical water temperature sections were made between late March and late October. These temperatures are recorded in table 11. They show a definite stratifica-

TABLE 11.--VERTICAL WATER TEMPERATURE SECTIONS, DEGREES F., IN FORK LAKE DURING 1939.

Depth, Feet	March 24	April 11	April 13	April 14	June 2	June 22	July 27	Aug. 1	Aug.14	Sept.25	Oct.25
Surface	60.0	47.0	48.0	46.8	79.1	81.0	87.9	86.0	79.3	73.0	60.2
1	59.5	47.0	48.0	46.8	78.2	81.0	86.9	86.0	79.2	73.0	60.0
2	57.0	47.0	46.6	46.0	77.6	80.6	84.2	82.0	79.0	72.7	60.0
3	54.0	47.0	45.8	45.6	77.0	79.6	82.4	79.0	78.0	70.3	59.9
4	50.3	47.0	44.3	45.0	76.8	78.7	80.5	77.7	76.8	70.3	57.6
5	47.4	47.0	43.5	44.5	76.1	75.9	78.6	76.7	75.3	70.2	57.6
6	46.0	47.0	43.2	44.0	74.5	73.0	75.8	74.4	74.0	70.1	57.6
7	45.5	46.7	43.2	43.5	71.7	71.0	73.7	73.2	72.8	70.0	57.6
8	45.5	46.7	43.2	43.5	69.5	70.0	73.0	71.7	71.4	70.0	57.6
9	45.5	46.7	43.2	43.5	....	68.8	....	....	....	....	....

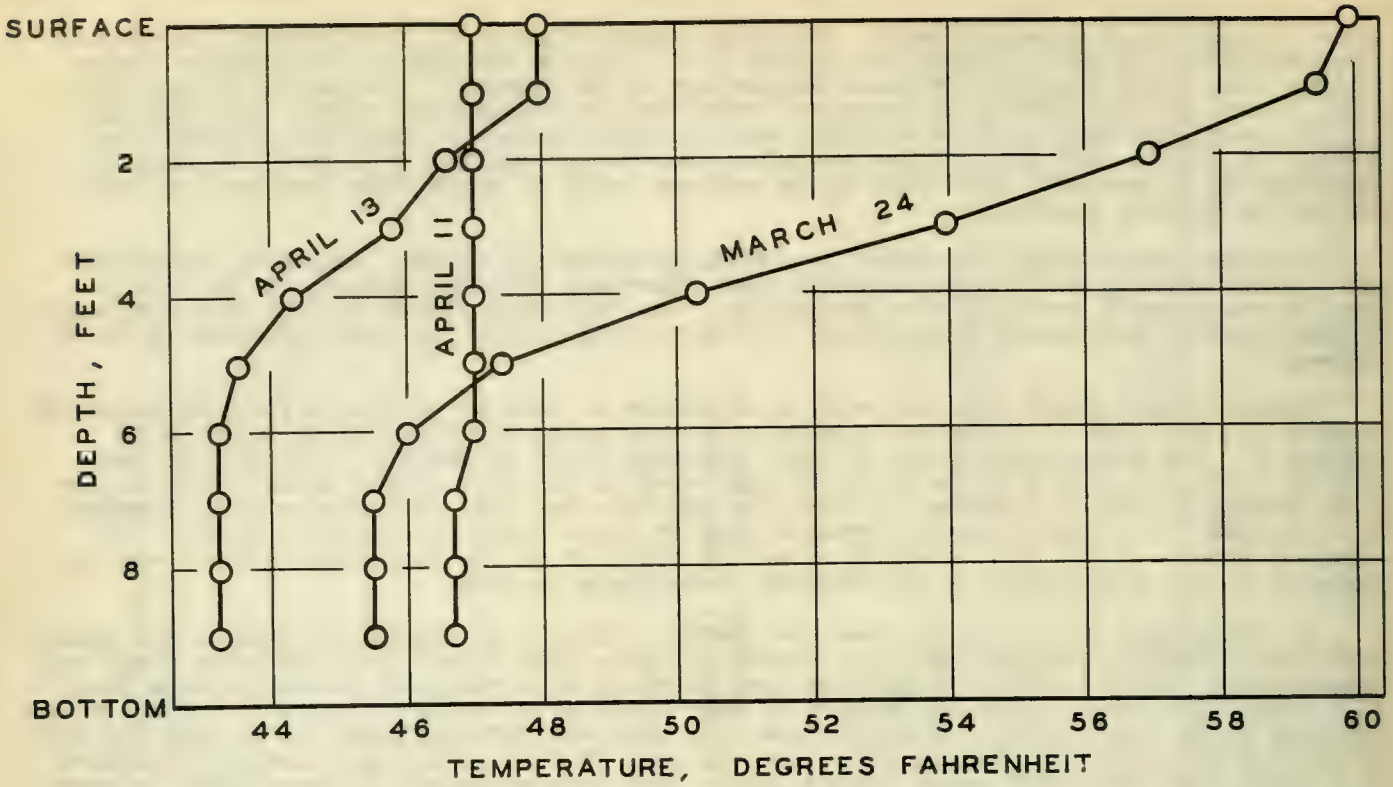


FIG.10.--Vertical temperature sections, degrees F., in Fork Lake during the spring of 1939, showing a period of temporary stratification, March 24.

tion throughout the summer. It is probable that, in the spring, stratification is established and broken up several times before the lake finally reaches the summer condition. Examples of these early spring changes are graphed in fig. 10. No instances of complete circulation were recorded during the summer. The first fall overturn, mentioned above as occurring on September 15, followed a violent storm. Temporary stratification was again found on September 25, while the weather was still warm. It is probable that during the fall there was occasionally complete stirring as in the spring.

An experiment on the effect of artificial stirring was made on August 14 by Dr. C. L. Schloemer and the senior author. Temperatures and oxygen samples were taken at 1-foot depth intervals, in the center of the lake, and then the lake was stirred for an hour with a 4-horsepower outboard motor anchored at one location 10 feet from shore. Temperatures and oxygen determinations were made again immediately afterward. The results of the stirring are shown in table 12. They suggest the practicability of artificial means for stirring oxygen into the lower waters of small artificial lakes.

TABLE 12--THE EFFECT ON STRATIFICATION OF STIRRING FORK LAKE WITH AN OUTBOARD MOTOR, AUGUST 14, 1939.

Depth, feet	Before Stirring		After Stirring	
	Temperature, Degrees F.	Oxygen, p.p.m.	Temperature, Degrees F.	Oxygen, p.p.m.
Surface	79.3	11.75	82.8	11.38
1	79.2	11.90	82.3	9.60
2	79.0	7.60	82.0	7.28
3	78.0	1.74	81.6	4.30
4	76.8	---	79.9	---
5	75.3	0.27	79.5	4.74
6	74.0	---	78.0	---
7	72.8	0.0	78.0	1.90
8	71.4	---	75.8	---

The sex organs were examined and the degree of sexual maturity was recorded for most of the fish removed from Fork Lake during 1939. The testes and ovaries of the largemouth bass were somewhat enlarged, although the fish did not reach maturity. Testes were small and translucent or white; ovaries were somewhat swollen, translucent or yellowish, but without definite eggs. No indication of nesting activity was observed in bass.

The 1938 brood of bluegills was sexually mature in 1939. In March, the gonads of both sexes were small, but during April they enlarged rapidly. By the latter part of April, males showed swollen, white testes and females had large, yellow ovaries filled with well-developed eggs. The old breeder bluegills showed about the same stage of sexual development as the 1938 brood.

The condition of the gonads was recorded as follows:

Immature. Testes of the males slender, translucent cords; ovaries of the females small, cigar-shaped, translucent and grayish-pink in color.

Poorly developed. Testes slightly enlarged, opaque and white; ovaries somewhat enlarged, opaque, pale yellow and developing eggs presenting a granular appearance.

Enlarged. Testes greatly enlarged, flattened, with wavy edges and opaque-white; ovaries greatly enlarged, oval, with large, distinct, solid, opaque, yellow eggs.

Spawning condition. Testes as above, but giving off milt, a watery white fluid, when gently pressed; ovaries as above, but turgid, giving off eggs when gently pressed. Eggs semiliquid, translucent, brownish-yellow and sticky.

Partly spent. Testes (after June) same as next above but less swollen; ovaries smaller but very similar to condition described as "enlarged." It is assumed that these fish have already spawned once.

Completely spent. Males with testes small and pinkish; ovaries of females flabby at first, contracted later, pinkish with granular appearance.

The percentages of fish taken each month showing each of the above conditions of sexual development are listed in table 13. In this table the sexes are separated and figures representing males underlined. Males matured earlier than females, and slightly more males than females were in spawning condition late in May. This lag in the development of the females seems to continue throughout most of the summer. In the collections of September 18-22, one female was in spawning condition and one partly spent, while all males were completely spent. The table indicates that the spawning period of the bluegill includes June, July and August. Observations on nesting confirm this information.

TABLE 13.--THE SEXUAL DEVELOPMENT OF BLUEGILLS TAKEN FROM FORK LAKE, 1939, SHOWN AS PERCENTAGES. FIGURES REPRESENTING MALES ARE UNDERLINED.

Date	Condition of Gonads					
	Immature	Poorly Developed	Enlarged	Spawning Condition	Partly Spent	Completely Spent
March 18-24. . .	71 / 56	29 / 44	...	...	...	...
April 13-18. . .	2	100 / 94	4	...	...	...
May 29-30. . . .	...	...	69 / 82	23 / 18	8	...
June 16-30	2	5	1	36 / 63	43 / 28	20 / 2
July 25-Aug. 3 .	...	3	1	29 / 24	56 / 67	14 / 6
Aug. 28-Sept. 8.	...	9	8	20 / 18	62 / 64	10 / 9
Sept. 18-22. . .	...	...	...	1	1	100 / 98
Oct. 27-30 . . .	...	...	...	...	...	100 / 100
Nov. 17-24 . . .	...	...	...	...	...	100 / 100

The original breeder bluegill males became sexually mature earlier than the males of the 1938 brood. In the March collection, 75 per cent of the young males appeared immature, while the older specimens were classed as poorly developed. In the May collection, 64 per cent of the old males were in spawning condition or partly spent, while only 10 per cent of the young were in the same condition. During late August there was a higher percentage of ripe fish among the young males than among the old males, but all were spent after September 18. In the females, however, this difference was not marked, and both the old and young were in spawning condition at about the same time. Two old females taken on June 16 showed atrophied gonads, suggesting complete loss of reproductive capacity.

Bluegill nests were first observed on May 28 (average water temperature at 3 feet, 77 degrees F.). On June 5, 40 nests were counted and nearly all contained eggs. A few bluegill fry were taken with a minnow seine on June 22, but most of the young had disappeared by June 28. On June 30, after an extensive search, only two young could be found.

On July 25, all nests were occupied by spawning bluegills. Many largemouth bass yearlings loitered about the nests. Whenever an opportunity offered, these bass entered the nests and fed--presumably on bluegill eggs or young fry. A few young bluegills were observed at this time among mats of *Potamogeton foliosus*.

On August 28, several bluegills occupied nests on the north side of the lake near the spillway. At this time bluegill fry were numerous and ranged in length from 0.50 to 1.25 inches. Young were still numerous along the shores on September 18. The largest were 2 inches long. Occupied bluegill nests were seen. During the period October 25-30, no young were seen along the edges of the lake.

FOOD OF THE BASS AND BLUEGILL

An abundant food supply is essential for rapid growth in fishes. The amount of food available must exceed the amount necessary to maintain the bodily processes, or there will be no growth at all. Most fish foods are developed within the body of the lake itself, although terrestrial insects and adult aquatic insects are taken by fish in numbers from the water's surface. Apparently, it is possible to maintain fish of assorted sizes and fish spawned year after year because the items of food also occur in graded sizes. Although there is some variation in the choice of foods selected by the kinds of fishes inhabiting small lakes, the item that is most abundant at any one time is usually the one most often eaten. Seasonal changes in food habits seem to depend upon changes in abundance of certain foods.

The optimum fish population is one that includes the kinds and numbers of fish to make the best use of all available foods without too keen competition for food of any one type. Since the food preferences of a fish change as it grows, a fish population including a wide range of sizes and ages is more efficient in utilizing the available food supply of a lake than one composed of fish of about equal sizes. Stunting is often the result of large broods competing for the same foods.

Stomachs were preserved from a large proportion of the bass and bluegills collected from Fork Lake each month--March through November, 1939. They were preserved in alcohol and data recorded on length, weight, sex, age, etc., of the individuals from which they were taken. Later, these stomachs were opened, the volume of the contents measured, and estimates made of the volume and number of each item. The data cover 671 bluegill stomachs and 299 largemouth bass stomachs. The purpose of this work was to learn what the bass and bluegills were eating and to follow changes in the diet from month to month. We are particularly interested in learning whether or not there is much competition between bass and bluegills in small lakes.

The volume of the stomach contents was determined by one of two methods: (1) by displacement of water in a graduated, conical, centrifuge tube; (2) by comparison with a series of blocks of graduated sizes from one-five-hundredth cubic centimeter to 2 cubic centimeters glued in a shallow box. The latter method was devised by the late R. E. Richardson.

The percentage, based on volume, of each item in each stomach was determined, and these percentages were averaged for each monthly collection of yearling bass, yearling bluegills and old bluegills. This procedure tends to reduce the importance of large items like crayfish, which were infrequent, and to increase the importance of smaller forms, such as insects commonly found in most stomachs.

Since most of the Fork Lake fish were taken in hoopnets which were set from 1 to 3 days before being lifted, these results are not strictly representative of what the fish were eating. Small items like bluegill fry, or small worms, digest rapidly. Large fish and crayfish require days to digest, even in warm weather. In cool weather, digestion may extend to a week or more. Heavily chitinized insects are included in the data, even

though the soft parts of the animals had been digested away. Although the results are not strictly representative, it is possible to compare the stomach contents of the different fish from month to month because these fish remained in the nets for similar lengths of time.

Two criteria can be used to express the degree of feeding: (1) the amount of food in the stomachs and (2) the percentage of empty stomachs. These are shown in table 14. Since the bass has a larger mouth than the bluegill and swallows larger animals which take a longer time to digest, it feeds at irregular intervals and is represented by a greater percentage of empty stomachs.

TABLE 14.--FEEDING ACTIVITY OF 299 BASS AND 671 BLUEGILLS TAKEN FROM FORK LAKE, 1939, AS DETERMINED BY STOMACH ANALYSIS.

Fish	Average Volume of Stomach Contents as Per Cent of Body Weight	Per Cent of Empty Stomachs
Old bluegills.	0.17	16
Yearling bluegills . .	0.27	12
Yearling bass.	0.33	27

Spawning activity in the bluegills, and warm water resulting in a rapid rate of digestion, may account for a high percentage of empty stomachs found in these fish during summer. About the same percentages of empty bass stomachs were found throughout the growing season.

In tables 15 and 16, important food items are shown as percentages of total weight of stomach contents of the 1938 broods of largemouth bass and bluegills. During some months there are indications of food competition; during others the important foods overlap but little.

This study of stomach contents suggests the following conclusions:

1. Crayfish of the year must have been exterminated early because none were found in bass stomachs after July.

2. The higher percentage of plants eaten by old bluegills may mean that the old fish were less active than the yearling fish in seeking animal foods and that they used plants as stuffing.

3. Bluegills and bass compete for insects wher fish are not available for the bass; however, bass eat more flying insects, and bluegills more immature aquatic insects.

4. The poor growth of bass during 1939 was due to a shortage of fish in their diet.

5. The most important groups of aquatic insects used for food in Fork Lake are the Diptera, Odonata and Hemiptera. Of these, the Diptera are consistently important as bluegill food and the Odonata as bass food.

HOOK-AND-LINE CATCH IN RELATION TO WATER TRANSPARENCY

Hook-and-line fishing began in March and ended in September, with a total of 55.2 man-hours. Fishing in Fork Lake was considered ordinarily good, although most of the bass caught were under legal length. Table 17 describes this hook-and-line catch.

The catch per man-hour varied from zero to 8.0, and the average catch for all dates combined was 4.37 fish per man-hour.

TABLE 15.--PERCENTAGES OF INSECTS IN THE STOMACHS OF OLD OR BREEDER BLUEGILLS, 1938 OR YEARLING BLUEGILLS AND YEARLING LARGEMOUTH BASS TAKEN FROM FORK LAKE, 1939.

Month and Group of Fish	Diptera		Ephemerida		Trichoptera Larvae	Odonata				Water-boatmen	Water-striders	Aquatic Beetles		Terrestrial Insects	Insect Fragments
						Damselflies		Dragonflies							
	Larvae	Adults	Nymphs	Adults		Nymphs	Adults	Nymphs	Adults			Larvae	Adults		
March															
Old bluegills. .	36.0	....	....	....	....	....	25.0	....	....	14.0	....	....	....	....	....
1938 bluegills .	11.4	....	....	....	....	....	....	....	....	3.3	....	....	....	....	5.3
Bass	....	....	....	....	....	....	....	....	....	80.0	....	4.0	....	15.0	1.0
April															
Old bluegills. .	10.2	....	....	....	0.2	....	....	....	....	2.2	....	4.0	....	1.0	7.0
1938 bluegills .	8.5	2.3	....	....	....	....	....	....	....	10.1	....	8.2	....	....	18.0
Bass	....	....	....	....	....	....	....	....	....	17.0	....	6.0	....	....	15.0
May															
Old bluegills. .	2.9	....	....	....	0.1	....	....	....	....	0.1	....	....	....	14.4	3.7
1938 bluegills .	15.3	0.3	....	....	0.3	....	....	15.3	....	....	....	....	0.3	....	4.2
Bass	4.0	5.9	....	....	1.1	....	17.2	9.2	3.5	8.2	8.1	3.0	....	1.1	18.8
June															
Old bluegills. .	3.1	3.7	....	....	....	....	5.6	....	....	....	....	....	....	2.6	3.7
1938 bluegills .	19.2	2.4	....	....	0.6	....	1.5	....	....	4.1	....	....	....	0.7	6.1
Bass	5.1	4.5	....	....	....	2.8	13.0	4.5	3.6	16.0	....	....	....	5.4	13.0
July															
Old bluegills. .	24.8	....	....	....	3.8	....	....	....	....	....	....	....	....	1.1	9.4
1938 bluegills .	16.8	0.5	1.0	....	4.5	....	....	....	....	2.2	....	1.0	....	0.9	11.2
Bass	....	....	....	....	....	....	28.6	....	....	1.3	....	....	....	....	....
August															
Old bluegills. .	30.5	....	....	....	3.8	....	....	....	....	11.0	....	....	....	....	3.8
1938 bluegills .	48.6	0.6	....	....	1.5	2.1	....	1.4	....	0.1	....	....	....	....	4.3
Bass	1.6	0.8	6.3	....	0.6	....	18.5	....	18.8	15.0	0.4	....	....	1.0	16.4
September															
Old bluegills. .	87.0	....	....	....	....	....	....	....	....	2.5	....	....	....	....	....
1938 bluegills .	70.1	....	....	....	....	2.7	....	4.0	....	1.3	....	....	....	....	6.5
Bass	3.9	3.1	....	....	....	0.4	14.9	8.9	9.3	8.4	....	1.8	6.7	4.0	8.6
October															
Old bluegills. .	11.0	....	....	....	....	....	....	....	....	45.0	....	....	....	....	....
1938 bluegills .	40.7	....	....	....	0.2	....	....	2.9	....	1.3	....	....	....	....	7.6
Bass	6.2	....	....	....	....	....	....	11.1	....	33.1	....	....	....	....	27.0
November															
Old bluegills. .	100.0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
1938 bluegills .	50.5	....	....	....	....	....	....	....	....	3.3	....	....	....	....	0.3
Bass	68.5	....	....	....	....	....	....	7.8	....	12.5	....	....	....	....	11.2

TABLE 16.--PERCENTAGES OF FOOD ITEMS (EXCLUSIVE OF INSECTS) IN THE STOMACHS OF OLD OR BREEDER BLUEGILLS, 1938 OR YEARLING BLUEGILLS AND YEARLING LARGEMOUTH BASS TAKEN FROM FORK LAKE, 1939.

Month and Group of Fish	Fish	Crayfish	Entomostraca			Mollusca		Coarse Aquatic Plants	Algae	Hydrachnids	Sponges	Sand and Scales	Miscellaneous
			Daphnia and Ceriodaphnia	Cyclops	Cypris	Snails	Sphaeriids						
March													
Old bluegills. .	....	....	25.0	....	....	....	....	....	....	....	....	....	....
1938 bluegills .	....	....	70.8	3.6	....	5.6	....	....	....	....	....	....	....
Bass	....	....	....	....	....	....	....	....	....	....	....	....	....
April													
Old bluegills. .	....	....	17.3	....	....	22.5	7.7	4.8	3.9	....	12.6	2.2	3.7
1938 bluegills .	....	....	38.6	1.4	....	8.1	....	1.6	....	....	....	....	3.2
Bass	12.0	25.0	25.0	....	....	....	....	....	....	....	....	....	....
May													
Old bluegills. .	....	....	....	....	....	12.1	20.4	10.4	17.9	....	7.1	9.1	1.9
1938 bluegills .	....	....	34.0	0.8	....	7.0	15.1	2.5	2.1	....	....	2.8	....
Bass	3.5	14.7	....	....	....	0.2	....	0.6	....	....	....	....	....
June													
Old bluegills. .	....	....	....	....	....	16.0	....	12.6	27.2	2.8	....	8.5	14.2
1938 bluegills .	....	....	18.2	0.4	3.6	13.5	0.8	10.1	8.3	0.7	0.3	8.8	....
Bass	....	29.9	....	....	....	1.8	....	0.1	....	....	....	....	....
July													
Old bluegills. .	....	....	....	2.1	....	0.4	....	25.2	29.6	....	....	3.5	....
1938 bluegills .	....	....	21.5	8.2	....	11.4	....	10.6	7.3	0.5	....	2.3	0.6
Bass	51.4	13.0	2.1	2.3	....	....	....	1.3	....	....	....	....	....
August													
Old bluegills. .	....	....	....	....	....	51.0	....	....	....	....	....	....	....
1938 bluegills .	....	....	19.0	6.0	....	7.0	....	4.5	1.0	....	....	4.0	....
Bass	20.3	....	....	....	....	....	....	....	....	....	....	0.3	....
September													
Old bluegills. .	....	....	....	....	....	1.5	....	8.0	1.0	....	....	....	....
1938 bluegills .	....	....	3.2	2.7	....	6.5	....	2.6	0.3	....	....	0.4	....
Bass	29.5	....	....	....	....	....	....	0.3	....	....	....	....	....
October													
Old bluegills. .	....	....	33.0	11.0	....	....	....	....	....	....	....	....	....
1938 bluegills .	....	....	31.3	0.2	0.3	11.4	0.5	0.6	1.4	....	....	1.1	....
Bass	7.5	....	....	....	1.2	1.2	....	12.5	....	....	....	....	....
November													
Old bluegills. .	....	....	....	....	....	....	....	....	....	....	....	....	....
1938 bluegills .	....	....	30.4	....	0.5	12.6	2.5	....	0.1	....	....	....	....
Bass	....	....	....	....	....	....	....	....	....	....	....	....	....

TABLE 17.--HOOK-AND-LINE CATCH FROM FORK LAKE, 1939.

Date	Bait Used	Number of Persons	Hours Fished	Number of Fish	Fish Per Man-Hour
March 24. . .	Pflueger pippin.	1	2.00	4	2.00
	Worms and spinner.	2	2.00	2	0.50
April 11. . .	Spinner fly.	1	0.33	0	0.00
April 13. . .	Spinner fly.	1	0.33	0	0.00
May 28. . . .	Trout flies.	2	4.50	39	4.33
May 30. . . .	Worms and Pflueger pippin.	8	2.13	131	7.69
June 22 . . .	Trout flies and Pflueger pippin. .	2	2.00	11	2.75
June 28 . . .	Trout flies.	3	2.66	25	3.13
July 25 . . .	Trout flies.	1	2.00	4	2.00
Sept. 8 . . .	Suet and grasshoppers.	2	3.00	5	0.83
Sept. 18. . .	Flies and small hair crayfish. . .	1	2.50	20	8.00
TOTAL MAN-HOURS. 55.2					
TOTAL FISH CAUGHT. 241					
AVERAGE CATCH PER MAN-HOUR . . . 4.37					

Success of fishing seemed to depend upon the transparency of the water; as the water became clearer, the catch of fish increased. Table 18 shows this relationship.

TABLE 18.--CORRELATION BETWEEN TRANSPARENCY AND FISHING.

Transparency, Feet	Number of Fish Per Man-Hour
0.5 to 2.0	2.04
2.0 to 2.5	2.86
3.5 to 4.5	6.53

Bass and bluegills feed by sight, and as the water clears the field of vision increases, allowing the fish to see both food and baits at greater distances.

EROSION CONTROL

In view of the apparent effect of transparency on fishing, erosion control becomes an important item in management practices for artificial lakes. In 1938, Dr. Lee E. Yeager, Forester of the Natural History Survey, suggested a plan of erosion control for Fork Lake. This plan has been partly carried out and is being continued in 1940. A small area of raw subsoil along the shore north of the dam needs to be revegetated. Here lespedeza is recommended for planting after a layer of dark loam has been worked over the clay surface. Several small gullies on the slopes above the lake need to be controlled by check dams of heavy sod. These dams should be about 15 feet apart. The silt which collects between them should be planted to lespedeza. Soil-binding shrubs should be planted on the lower face of the dam and the steep slopes around the lake.

DISCUSSION

More than a half century of fisheries investigation carried on by the Illinois Natural History Survey and its predecessors, the State Laboratory of Natural History and the State Museum of Natural History, have forced us to the conclusion that rather complete information on a few individual bodies of water over a long period of time can give more valuable information than a much larger volume of data taken at various seasons from hundreds of different localities. Fork Lake is being used intensively as an experimental lake until the time when the experimental lakes at Fox Ridge State Park, near Charleston, and Dixon Springs Lake, in extreme southern Illinois, are completed and put into operation.

Although Fork Lake has an area of only 1.38 acres, our fisheries investigations there have given us much valuable experience in planning the investigational program to be carried out in these larger lakes (23 and 82 acres, respectively).

A deliberate attempt has been made to simplify the investigations at Fork Lake by limiting the fish population to largemouth bass and bluegills. The yield during 1939 was 162 pounds per acre and we propose to attempt to double it during 1940. The carrying capacity of this lake for carnivorous fish, as estimated from the 1938 census, is about 300 pounds per acre. Since the fish population now consists mostly of yearling bass and yearling bluegills, it does not seem likely that the food resources of the lake are being

utilized as efficiently as they will be when the lake contains fish of a greater range of sizes and ages. There is a tendency to underfish small lakes in Illinois and to protect young fish from all kind of fish predators. Under these conditions, large, dominant broods of fish appear at 3- to 5-year intervals, tending to make hook-and-line fishing irregular. When these lakes are fished intensively, the broods of young produced each year grow rapidly and the success of fishing is more nearly uniform.

It has been suggested by Ellis (1937) and others that impounded waters decline in fertility with increasing age. Measurements of fish yields and carrying capacity of old artificial lakes do not support this view. As newly constructed lakes are usually stocked with a small number of breeders of desirable kinds, lack of crowding makes possible good fishing for the first few years. Later, excessive multiplication of these fish produces stunted, slow-growing broods not attractive to hook-and-line fishermen. In addition, the introduction of undesirable kinds through careless stocking, or by escaped bait, tends to encourage the production of a large undesirable population which competes with desirable kinds for food. In lakes with mixed populations, intensive fishing for certain kinds, such as bass, bluegills and other species which take the hook, tends to relieve the competition on the less desirable kinds and causes them, rather than the desirable kinds, to increase. Furthermore, the undesirables are usually fish such as carp, buffalos, suckers, bullheads and gizzard shad, which roil the bottom muds and interfere with the feeding and biting of those kinds, such as bass, crappies, bluegills and other sunfishes, which depend on their sense of sight. In such cases, additional stocking does not improve fishing but merely aggravates the condition of overcrowding.

The ordinary evidence used to support the claim of a loss of fertility would have been borne out by the history of Fork Lake, where success of fishing declined to a very low point over a period of years. When poison was applied and a census made, the lake's carrying capacity for fish was found to be very high, but the fish population consisted of stunted hook-and-line species and undesirables. After these were replaced with small numbers of desirable fish, the lake again produced good fishing. Fishing in Horseshoe Lake was greatly improved in much the same manner. (Thompson & Bennett 1938; and Ellis 1937, discussion).

Small percentages of fish of desirable sizes and evidence of slow growth are often misinterpreted in making recommendations for fish management. Too often, improved spawning facilities, greater length limits and other restrictions have been applied to correct such conditions. To us it appears that the remedy is the exact opposite--to restrict reproduction and to thin the population so that growth rates will be increased and more fish reach attractive sizes.

SUMMARY

1. In 1939, after Fork Lake had been stocked in 1938 with 270 adult bluegills and 1,440 largemouth bass fry, 1,289 fish weighing 223.4 pounds were removed. This cropping was done at monthly intervals at the rate of about 25 pounds of fish per month. The total yield for 1939 was at the rate of 162 pounds of fish per acre.

2. The lake also produced about 99 pounds of turtles, 1.6 pounds of bullfrogs and 14 muskrats. On the 60 acres of land immediately surrounding Fork Lake, 49 quail and 134 rabbits were killed by hunters.

3. Previous to the elimination of the old population and the restocking in 1938, only 1.8 per cent of the fish of Fork Lake were of desirable sizes. During 1939, 39.2 per cent of all fish taken with inch-mesh hoopnets or hook and line were of desirable sizes (see tables 3 and 4). At the end of the season this percentage was much higher.

4. A few bass reached legal length at the age of 13 to 14 months. Yearling bluegills taken from the lake in September, October and November averaged more than 6 inches in length. The breeder bluegills grew rapidly in 1938, but slowly in 1939.

5. The index of condition was high in bluegills until the onset of the spawning period, when it dropped. A slight improvement in condition appeared in late August and September, followed by a drop in October and November. Bass were of average plumpness when compared with those of other Illinois waters, and did not vary much throughout the year.

6. Many fish from Fork Lake were heavily parasitized. This condition did not seem to affect their growth.

7. Some of the yearling bluegills had formed annuli on their scales before April 18, and all of them had formed annuli by the end of May. Most breeder bluegills began annulus formation later than the yearlings and did not complete this formation until October. Annulus formation in bass extended from mid April to late September. A second or false annulus appeared in many fish. Thirty-eight per cent of the yearling bass and 24 per cent

of the yearling bluegills taken after false annuli were first observed in the respective species formed more or less distinct second annuli; in 6 per cent of the bass and 10 per cent of the bluegills the second annulus was as definite as a true annulus, and might be mistaken for it.

8. In bass, scale measurements were found to be directly proportional to the length of the fish. In bluegills, this ratio was found to change as the fish grows.

9. Stunted breeder bluegills transplanted from Homewood Lake more than doubled their weight in 12 to 15 months in Fork Lake. These fish produced young in Fork Lake that were heavier at 15 months than they had been at ages between 2 and 5 years when in Homewood Lake.

10. Water temperatures in Fork Lake remained about midway between minimum and maximum daily air temperatures during the time covered by this study in 1939. The active growing season for fish was about 6 months long. Transparency and water levels were closely correlated with rainfall. Fork Lake is thermally stratified from late spring to early fall. Artificial circulation was produced with a small outboard motor.

11. Bluegills spawned at the age of 1 year, but the bass did not. The spawning period for bluegills extended from early June through August.

12. Analyses of bass and bluegill stomachs in 1939 showed some competition for insects. All fish and crayfish in these stomachs had been taken by bass, and almost all of the entomostraca, vegetation and mollusks by bluegills.

13. The hook-and-line catch in Fork Lake averaged 4.37 fish per man-hour. The catch were greatest when the water was clearest.

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